Report of the New York State College of Agriculture at Cornell ...

New York State College of Agriculture, Cornell University. Agricultural Experiment Station

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TWENTY-SIXTH ANNUAL REPORT

OF THE

New York State College of Agriculture

AT

CORNELL UNIVERSITY

AND THE

Agricultural Experiment Station

Established under the Direction of Cornell University

ITHACA, N. Y.

1913

PART I

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JANUARY 15, 1914

TWENTY-SIXTH ANNUAL REPORT

OF THE

New York State College of Agriculture at Cornell University and the Agricultural Experiment Station Established under the Direction of Cornell University

STATE OF NEW YORK

DEPARTMENT OF AGRICULTURE

ALBANY, *January* 15, 1914

To the Honorable the Legislature of the State of New York:

In accordance with the provisions of the statutes relating thereto, I have the honor to transmit herewith the Twenty-sixth Annual Report of the New York State College of Agriculture at Cornell University, as a part of the Twenty-first Annual Report of the Commissioner of Agriculture.

CALVIN J. HUSON,
Commissioner of Agriculture.

NEW YORK STATE COLLEGE OF AGRICULTURE

FACULTY

Jacob Gould Schurman, A.M., D.Sc., LL.D., President of the University.
Liberty Hyde Bailey, M.S., LL.D., Director of the College of Agriculture and Dean of the Faculty.
Isaac Phillips Roberts, M.Agr., Professor of Agriculture, Emeritus.
John Henry Comstock, B.S., Professor of Entomology and General Invertebrate Zoology.
Henry Hiram Wing, M.S. in Agr., Professor of Animal Husbandry.
John Craig, M.S. in Agr., Professor of Horticulture.
Thomas Lyttleton Lyon, Ph.D., Professor of Soil Technology.
Herbert John Webber, M.A., Ph.D., Professor of Plant-breeding.
John Lemuel Stone, B.Agr., Professor of Farm Practice and Farm Crops.
James Edward Rice, B.S.A., Professor of Poultry Husbandry.
George Walter Cavanaugh, B.S., Professor of Chemistry in its Relations with Agriculture.
George Nieman Lauman, B.S.A., Professor of Rural Economy.
Herbert Hice Whetzel, A.B., M.A., Professor of Plant Pathology.
Elmer O. Fippin, B.S.A., Professor of Soil Technology.
George Frederick Warren, Ph.D., Professor of Farm Management.
William Alonzo Stocking, jr., M.S.A., Professor of Dairy Industry.
Charles Scoon Wilson, A.B., M.S.A., Professor of Pomology.
Charles Henry Tuck, A.B., Professor of Extension Teaching.
Albert Russell Mann, B.S.A., Secretary to the College of Agriculture, Registrar, and Professor of Agricultural Editing.
Wilford Murray Wilson, M.D., Professor of Meteorology.
Walter Mulford, B.S.A., F.E., Professor of Forestry.
James George Needham, Ph.D., Professor of General Biology, Limnology, and Nature Study.
Bryant Fleming, B.S.A., Professor of Landscape Art.
Harry Houser Love, Ph.D., Professor of Plant-breeding Investigations.
Arthur Witter Gilbert, Ph.D., Professor of Plant-breeding.
Donald Reddick, Ph.D., Professor of Plant Pathology.
Edward Gerrard Montgomery, M.A., Professor of Farm Crops.
——— ———, Professor of Rural Education.
Flora Rose, B.S., M.A., Professor of Home Economics.
Martha Van Rensselaer, A.B., Professor of Home Economics.
William Albert Riley, Ph.D., Professor of Insect Morphology and Parasitology.
James Adrian Bizzell, Ph.D., Professor of Soil Technology.
Glenn Washington Herrick, B.S.A., Professor of Economic Entomology.
Howard Wait Riley, M. E., Professor of Farm Mechanics.
Harold Ellis Ross, M.S.A., Professor of Dairy Industry.
Hugh Charles Troy, B.S.A., Professor of Dairy Industry.
——— ———, Professor of Pomology.
Samuel Newman Spring, B.A., M.F., Professor of Forestry.
Merritt Wesley Harper, M.S., Assistant Professor of Animal Husbandry.
William Charles Baker, B.S.A., Assistant Professor of Drawing.
Clarence Arthur Rogers, M.S.A., Assistant Professor of Poultry Husbandry.
Cyrus Richard Crosby, A.B., Assistant Professor of Entomological Investigations.

Elmer Seth Savage, M.S.A., Ph.D., Assistant Professor of Animal Husbandry.
Lewis Knudson, B.S.A., Ph.D., Assistant Professor of Plant Physiology.
Kenneth Carter Livermore, B.S. in Agr., Assistant Professor of Farm Management.
Alvin Casey Beal, Ph.D., Assistant Professor of Floriculture.
Mortier Franklin Barrus, A.B., Ph.D., Assistant Professor of Plant Pathology.
James Chester Bradley, Ph.D., Assistant Professor of Systematic Entomology.
E. Gorton Davis, B.S., Assistant Professor of Landscape Art.
Edward Russell Minns, B.S. in Agr., Assistant Professor in Extension Work in Farm Crops.
John Bentley, jr., B.S., M.F., Assistant Professor of Forestry.
——— ———, Assistant Professor of Forestry.
Lewis Josephus Cross, B.A., Ph.D., Assistant Professor of Agricultural Chemistry.
Robert Matheson, M.S. in Agr., Ph.D., Assistant Professor of Biology.
George C. Embody, Ph.D., Assistant Professor of Agriculture.
Clyde Hadley Myers, M.S., Ph.D., Assistant Professor of Plant-breeding.
Harry O. Buckman, M.S.A., Ph.D., Assistant Professor of Soil Technology.
Mrs. Helen Binkerd Young, B.Arch., Assistant Professor of Home Economics.
Alice Gertrude McCloskey, A.B., Associate in Rural Education.
Charles Cleveland Hedges, A.B., Ph.D., Instructor in Agricultural Chemistry.
George Walter Tailby, jr., B.S.A., Instructor in Animal Husbandry and Superintendent of Live-stock.
Edward Sewall Guthrie, M.S. in Agr., Instructor and Investigator in Dairy Industry.
Paul Work, B.S., A.B., Instructor and Investigator in Olericulture.
Ralph Hicks Wheeler, Instructor in Extension Teaching.
Roy David Anthony, B.S. in Agr., Instructor in Pomology.
Lee Briggs Cook, M.S. in Agr., Instructor in Dairy Industry.
Harry M. Fitzpatrick, A.B., Instructor in Plant Pathology.
Arthur Lee Thompson, M.S. in Agr., Instructor and Investigator in Farm Management.
Byron Burnett Robb, B.S. in Agr., Instructor in Farm Mechanics.
Ray Eugene Deuel, B.S. in Agr., Instructor in Animal Husbandry.
Earl Whitney Benjamin, M.S. in Agr., Instructor in Poultry Husbandry.
Harvey Lyon Ayres, Extension Instructor in Dairy Industry.
——— ———, Instructor in Plant Physiology.
Charles Truman Gregory, B.S. in Agr., Instructor in Plant Pathology.
Walter Warner Fisk, M.S. in Agr., Instructor in Dairy Industry.
Thomas Joseph McInerney, M.S. in Agr., Instructor in Dairy Industry.
Horace Mann Pickerill, B.S. in Agr., Instructor in Dairy Industry.
Edward Mowbray Tuttle, B.S.A., Instructor in Rural Education.
Rhett Youmans Winters, M.S., Ph.D., Instructor in Plant-breeding.
Royal Gilkey, B.S.A., Instructor in Extension Teaching, and Supervisor of Mailing Division and Reading-Courses.
Juan Estevan Reyna, E.E., Instructor in Drawing.
Martin John Prucha, Ph.B., M.S., Instructor in Plant Physiology.
Charles Piper Smith, B.S., A.M., Instructor in Plant Pathology.
William Howard Rankin, A.B., Instructor in Plant Pathology.
Carl Edwin Ladd, B.S. in Agr., Instructor in Farm Management, in cooperation with the United States Department of Agriculture.
Clara Browning, B.S., Instructor in Home Economics.
Asa Carlton King, B.S.A., Instructor in Extension Teaching.
Halsey B. Knapp, B.S., Instructor in Pomology.
Anna Clegg Stryke, A.B., Artist and Instructor in Entomology.

Other Officers of Instruction and Administration

Anna Botsford Comstock, B.S., Lecturer in Nature Study.
Mrs. Ida Schwedler Harrington, Extension Lecturer in Home Economics.
John Walton Spencer, Agent in Extension Work.
G. Clayton Dutton, Assistant in Cheese-making.
Charles Herbert Van Auken, Assistant in Animal Husbandry.
Ada Eljiva Georgia, Assistant in Nature Study.
Emmons William Leland, B.S.A., Assistant in Soil Technology.
John Thomas Lloyd, A.B., Assistant in Limnology.
Walter Stanley Lyon, Assistant in Poultry Husbandry.
Lewis Merwin Hurd, Assistant in Poultry Husbandry.
Robert Palmer Trask, Assistant in Poultry Husbandry.
Frank Elmore Rice, A.B., Assistant in Agricultural Chemistry.
David Ely Fink, B.S.A., Assistant in Economic Entomology.
Carl Ilg, Curator in Entomology.
Jacobus Christian Faure, B.S., Assistant in Entomology.
Otis F. Curtis, M.S., Assistant in The Farm Course
David A. Crawford, M.S., Assistant in Biology.
Mary A. Lyon, B.A., Assistant in Biology.
Blanche E. Stafford, M.S., Assistant in Biology.
Willis Robert Fischer, Laboratory Assistant in Plant Pathology.
Irvin Torrance Francis, Assistant in Plant Pathology.
Charles Chupp, Assistant in Plant Pathology.
Clyde Evert Leighty, A.B., Ph.D., Assistant in Plant-breeding.
Tryggve Emil Schreiner, Assistant in Poultry Husbandry.
Eugene Davis Montillon, Assistant in Landscape Art.
William J. Robbins, A.B., Assistant in Plant Physiology.
James Kenneth Wilson, B.S., Assistant in Plant Physiology.
Ralph Simpson Nanz, B.S., Assistant in Plant Physiology.
Delmont Westervelt, Mechanic to Department of Farm Mechanics.
Lucy Harriet Ashton, Assistant Registrar.
Louis H. Moulton, Superintendent of the Farms.
Thomas Wolcott, Foreman of Pomology Grounds.
George Walter Tailby, Foreman of the Farms.
Charles Edward Hunn, Foreman of Grounds.
Arthur Bradford Cornelius, Assistant Gardener.
Walter Gernet Krum, Superintendent of Poultry Plant.
Andrew Jackson Lamoureux, Librarian.
Herbert W. Teeter, Superintendent of Plant-breeding Garden.
Edwin S. DeLany, Clerk.
Laura McLallen Van Auken, Clerk in Department of Dairy Industry
Gilbert Arthur Renney, Superintendent of Mailing Rooms.

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION

EXPERIMENTING STAFF

The regular bulletins of the Station are sent free to persons residing in New York State who request them.

November 22, 1913

The Governor of the State of New York,
Albany, New York.

The Secretary of the Treasury,
Washington, D. C.

The Secretary of Agriculture,
Washington, D. C.

The Commissioner of Agriculture,
Albany, New York.

The Act of Congress, approved March 2, 1887, establishing Agricultural College Experiment Stations in connection with the Land Grant Colleges, contains the following provision: "It shall be the duty of each of said stations, annually, on or before the first day of February, to make to the Governor of the State or Territory in which it is located, a full and detailed report of its operations, including a statement of receipts and expenditures, a copy of which report shall be sent to each of said stations, to the said Commissioner of Agriculture, and to the Secretary of the Treasury of the United States."

And the Act of the Legislature of the State of New York, approved April 12, 1906, providing for the administration of the New York State College of Agriculture at Cornell University, contains the following provision: "The said University shall expend such moneys and use such property of the State in administering said College of Agriculture as above provided, and shall report to the Commissioner of Agriculture in each year on or before the first day of December, a detailed statement of such expenditures and of the general operations of the said College of Agriculture for the year ending the thirtieth day of September then next preceding."

In conformity with these mandates I have the honor to submit on behalf of Cornell University the accompanying report for the year 1912–1913, signed by the Director and the Acting Director of the College.

This report, along with the accompanying abstracts of the work of the different departments of the College and the copies of the numerous publications during the year, presents such a complete conspectus of the operations of the institution that any supplementary statement may be regarded as superfluous.

I cannot, however, close this communication without expressing the sense of loss felt by the College and the whole university community in consequence of the resignation of Director Bailey, which took effect on August 1. He has given to the College and to the agricultural interests of the State for many years not only enthusiasm and devotion — precious as these are — but also his great abilities as a scientist, an organizer, and a leader; and the College of Agriculture at Cornell University will long retain the impress of his efficient and highly successful administration as Director.

On the retirement of Director Bailey on August 1 his place was filled by the appointment of William Alonzo Stocking, jr., Professor of Dairy Industry, as Acting Director.

Respectfully submitted,

JACOB GOULD SCHURMAN,

President of Cornell University.

REPORT OF THE DIRECTOR OF THE NEW YORK STATE COLLEGE OF AGRICULTURE

To the President of the University:

SIR:— The past year has been a time of unusual activity in the College of Agriculture. The increase in students has been large, the extension work has grown rapidly, the research projects have increased and some of them have matured, and many new movements and enterprises have been discussed and put under way. The wholesome spirit of the College (which is the propelling force in any educational institution) has been more effective than ever before. In all its activities, the College has had a year of unusual momentum.

The College is administered on a cooperative basis as between staff and students, all partaking freely in the work in a spirit of comradeship. The social element is a strong factor in the processes in the institution. The students are stimulated to take part in the government of the College and to make direct and useful suggestions touching the administration. They are encouraged to form discussion clubs representing the subject matter of their work. Many such clubs are now established. All these clubs are free and open to all students and to all members of the staff. These bodies become essentially a part of the educational organization of the College. All of them are represented in a committee of the general students' organization, so that they are practically under control of the entire student body in the College of Agriculture. The Director's office is able to extend itself through these clubs when it desires to reach the student body. Inasmuch as these more or less organized units are partakers in the administration of the College, it is becoming evident that they should have headquarters either in separate small buildings or in a central students' building in which the groups may be found, which will make them responsible, and which will provide meeting places for discussion and room for the collecting of books and specimens and materials. The Lazy Club of the old Department of Horticulture had for years a building of its own. There is a growing feeling in the College that other groups should have small buildings, erected in part or entirely by the groups themselves, and properly placed in the regular landscape scheme. The tendency for colleges is to become too institutional in the character of the buildings. The large buildings are impersonal. In a college in which social cooperation is a strong element there should be small

and personal units here and there at convenient and proper places, which are accessible to students on their own account and which may contribute something of the informality and unofficial character that is so essential to the best growing of educational enterprises. If the students are to be cooperating factors, then the fact should be frankly and visibly recognized. Such buildings should, of course, belong to the institution and be under restriction as to use and management; but they should represent the interests of the student body.

STUDENTS AND STAFF

The registration of students in the New York State College of Agriculture for the year 1912–1913 (including the Summer School of 1913) is as follows:

Graduate students		111
Regular students:		
Seniors	172	
Juniors	218	
Sophomores	320	
Freshmen	393	
		1,103
Special students		161
Winter-course students:		
General Agriculture	266	
Poultry Husbandry	117	
Dairy Industry	86	
Horticulture	70	
Home Economics	58	
		597
Summer-school students		333
Total		2,305

Number of women in regular course 1912–1913	151
Number of women in special course 1912–1913	18
Number of women in winter courses 1912–1913	99
Total	268

The general growth of the student body in the College of Agriculture is indicated in the following statement of the number of regular and

special students that have registered in all the years from 1868 to the present:

1868–1869		
Regulars		30
1869–1870		
Regulars		24
1870–1871		
Regulars		20
1871–1872		
Regulars		13
1872–1873		
Regulars		15
1873–1874		
Regulars		7
1874–1875		
Regulars	17	
Specials	1	
		18
1875–1876		
Regulars	9	
Specials	2	
		11
1876–1877		
Regulars	28	
Specials	1	
		29
1877–1878		
Regulars	37	
Specials	5	
Graduates	1	
		43
1878–1879		
Regulars	34	
Specials	7	
		41
1879–1880		
Regulars	33	
Specials	2	
		35
1880–1881		
Regulars		26
1881–1882		
Regulars	16	
Specials	1	
Graduates	1	
		18
1882–1883		
Regulars		15
1883–1884		
Regulars		13
1884–1885		
Regulars	18	
Specials	2	
		20
1885–1886		
Regulars		23
1886–1887		
Regulars	33	
Specials	5	
		38
1887–1888		
Regulars	33	
Specials	12	
		45
1888–1889		
Regulars	37	
Specials	21	
Graduates	2	
		60
1889–1890		
Regulars	28	
Specials	21	
Graduates	3	
		52
1890–1891		
Regulars	32	
Specials	20	
Graduates	6	
		58
1891–1892		
Regulars	22	
Specials	19	
Graduates	12	
		53
1892–1893		
Regulars	24	
Specials	24	
Graduates	9	
Winter courses	48	
		105
1893–1894		
Regulars	25	
Specials	20	
Graduates	9	
Winter courses	61	
		115
1894–1895		
Regulars	24	
Specials	21	
Graduates	9	
Winter courses	77	
		131
1895–1896		
Regulars	30	
Specials	21	
Graduates	13	
Winter courses	83	
		147
1896–1897		
Regulars	34	
Specials	34	
Graduates	22	
Winter courses	60	
		150

1897–1898		
Regulars	56	
Specials	28	
Graduates	20	
Winter courses	93	
		197

1898–1899		
Regulars	46	
Specials	39	
Graduates	17	
Winter courses	89	
		191

1899–1900		
Regulars	43	
Specials	45	
Graduates	19	
Winter courses	83	
		190

1900–1901		
Regulars	48	
Specials	50	
Graduates	23	
Winter courses	94	
		215

1901–1902		
Regulars	49	
Specials	43	
Graduates	22	
Winter courses	96	
		210

1902–1903		
Regulars	60	
Specials	53	
Graduates	18	
Winter courses	121	
		252

1903–1904		
Regulars	77	
Specials	64	
Graduates	21	
Winter courses	134	
		296

1904–1905		
Regulars	98	
Specials	90	
Graduates	31	
Winter courses	199	
		418

1905–1906		
Regulars	128	
Specials	102	
Graduates	40	
Winter courses	248	
		518

1906–1907		
Regulars	145	
Specials	133	
Graduates	36	
Winter courses	244	
		558

1907–1908		
Regulars	206	
Specials	142	
Graduates	43	
Winter courses	270	
		661

1908–1909		
Regulars	268	
Specials	145	
Graduates	58	
Winter courses	364	
		835

1909–1910		
Regulars	419	
Specials	120	
Graduates	57	
Winter courses	371	
		967

1910–1911		
Regulars	597	
Specials	169	
Graduates	80	
Winter courses	477	
Summer school	128	
		1,451

1911–1912		
Regulars	806	
Specials	180	
Graduates	119	
Winter courses	451	
Summer school	223	
		1,779

1912–1913		
Regulars	1,103	
Specials	161	
Graduates	111	
Winter courses	597	
Summer school	333	
		2,305

The conditions governing the entrance of special students have changed much in recent years. Only farm residents of New York State are now admitted as specials, and they are such persons as have had the proper common school advantages and have had sufficient experience and general training to enable them to make the most of optional courses of study extending over one or two years. Persons who have had the advantage of regular preparation for entrance are admitted to the regular

courses. There are considerable fluctuations in the numbers of special students, but in proportion to the entire student body the percentage is now small. Some of the best and most competent students in the institution have always been among the specials. The experience of the College with these special students, extending now over many years, raises the question as to whether the formal entrance requirements of educational institutions represent the most essential elements in qualification for college work. The enrollment of special students in the College of Agriculture for the years 1907–1908 to 1912–1913 inclusive is as follows:

	Total enrollment *	Enrollment of specials	Percentage of specials
1907–1908	348	142	41
1908–1909	413	145	35
1909–1910	539	120	22
1910–1911	766	169	22
1911–1912	986	180	18
1912–1913	1,264	161	13

The entrance requirements in the College of Agriculture have been rigidly enforced. The faculty has now gone so far as to take the very desirable action of admitting no student who has any shortage in points of entrance.

The staff of the College has necessarily grown rapidly, in order to enable the institution to handle satisfactorily the increasing volume of work. The work is not alone the teaching of students who come to the institution. The projects of investigation and research are demanding much attention, and the extension work has grown rapidly and is still not able to meet the demands. The total appointive staff in the College of Agriculture now comprises about three hundred persons, of whom approximately two hundred are engaged directly in teaching and investigation.

The number of separate courses to be given in the College of Agriculture in the year 1913–1914, exclusive of winter courses and summer courses, is 236, distributed as follows:

Agricultural Chemistry	9
Animal Husbandry	11
Botany	14
Dairy Industry	17
Drawing	4
Entomology, Biology, and Nature Study	32
Extension Teaching	3
Farm, The	1
Farm Crops	6
Farm Management	4
Farm Practice	1
Floriculture	13
Forestry	19

* This includes regular and special students only, and does not include postgraduate and winter-course students.

Home Economics	16
Landscape Art	11
Meteorology	1
Plant-breeding	8
Plant Pathology	10
Pomology	13
Poultry Husbandry	13
Rural Economy	7
Rural Engineering	7
Soil Technology	8
Vegetable-gardening	8
Total	236

EXTENSION OF THE COLLEGE YEAR

Following a discussion extending over some years, the faculty in agriculture has taken action to make the college year match the natural year. This action has been approved by the Board of Trustees. It is expected that the enlargement of the college year will go into effect with the beginning of the summer term of 1914 or with the beginning of the regular college year in the autumn of 1914. It is proposed to establish three terms, covering the entire twelve months. The officers in the teaching staff are not to be allowed to teach more than nine months in any one year. The educational organization of the new plan is to be worked out by committees and faculty in the coming year.

It is not the idea to make the Summer School, which is now well established in the College of Agriculture, the third, or summer, term; but a regular term coordinate with other terms, except shorter in length, is to be added.

Even when the third term is established, it is expected that the Summer School will be held in addition thereto for teachers and others, in the same way in which the winter courses are held in addition to the regular college year. In fact, it may be expected that numbers of short and special courses of instruction will be added as necessities arise. The faculty in agriculture has recently established a ten-days course in fancy-cheese- and ice-cream-making and a one-week course for managers of dairy establishments. The main body of instruction is to be continued throughout the twelve months, and it is hoped that the College will never be closed; and corollary to this general educational program will be the special courses and opportunities to meet the needs of the people. The College of Agriculture exists for the double purpose of providing thoroughgoing training for the students who matriculate, and of giving aid, encouragement, and point of view to the residents of the State who are interested in its work.

Perhaps the most significant development in the way of side courses is the establishment of the School for Leadership in Country Life, a special account of which may now be given.

SCHOOL FOR LEADERSHIP IN COUNTRY LIFE

For a number of years the College of Agriculture was urged to establish a school for the training of social workers in rural communities. In response to this demand, there was held July 21 to 28, 1911, a Training Conference for Rural Leaders. The conference lasted for eight days and consisted of three regular class periods in the forenoon, two in the afternoon, and one in the evening of each day. The total attendance was twenty-three persons, coming from five States. The second conference, held June 25 to July 5, 1912, was lengthened to ten days and the attendance was increased to fifty-nine persons, coming from ten States.

The success of these two conferences indicated the desirability of establishing such a training conference as a part of the regular work of the College. On June 24 to July 4, 1913, the third of these conferences was held, under the name of the School for Leadership in Country Life. There was an attendance of ninety persons from twenty-two States and from Washington, D. C., and Canada. The persons in attendance were farmers, farm women, rural teachers and principals, district superintendents of schools, college professors, college students, grange officers and workers, farmers' institute lecturers, farm bureau agents, rural librarians, a rural social investigator, rural pastors, secretaries of rural Young Men's and Young Women's Christian Associations, a rural Sunday-school superintendent, representatives of rural philanthropic enterprises, boy scout officers, a country merchant, a civil engineer, and a kindergartner. These persons came from the States of New York, Massachusetts, Rhode Island, Connecticut, New Jersey, Pennsylvania, Maryland, South Carolina, Georgia, Alabama, Mississippi, Kentucky, Illinois, Iowa, Minnesota, Missouri, Nebraska, Louisiana, Texas, Arizona, Montana, and California, from Washington, D. C., and from Toronto, Canada.

From the beginning the purpose of the school has been to provide a course of training for all classes of rural leaders and to offer fundamental courses that would be of value to all rural social workers, rather than to offer specialized courses for particular classes of rural workers. The desirability of providing a three-years graded course leading to a certificate was foreseen, and in the school this year both first-year and second-year courses were offered. Third-year courses will be added to the school next year (to be held June 23 to July 3, 1914, inclusive).

The courses of instruction offered this year were as follows:

Courses in Rural Leadership.— First-year students: (1) The Psychology of Leadership; (2) The Study of Human Nature. Second-year students: (1) The Pedagogy of Leadership; (2) Group Organization.

Courses in Rural Ethics.— First-year students: (1) The Development

of Rural Character. Second-year students: (1) Rural Personal Ideals; (2) The Family and the Rural Problem.

Courses in Rural Sociology.— First-year students: (1) Social Aspects of Rural Life; (2) Principles of Rural Sociology. Second-year students: (1) The Social Function of Rural Institutions; (2) Cooperation and Federation of Rural Social Agencies.

Courses in Rural Economics.— First-year students: (1) The Field of Rural Economics; (2) Some Applications of Economic Principles to the Problems of Rural Social Life. Second-year students: (1) Business Organization and Cooperation.

Courses on the Farm Home and the Family.— Second-year students: (1) The Farm Boy; (2) The Farm Girl; (3) The Farm Woman; (4) Leadership for Farm Women and Girls.

Course on the Rural Social Survey, for second-year students.

Course in Extension Teaching in Agriculture, for first-year students.

Course in Rural Play, for all students.

Course in Rural Athletics, for all students.

The afternoon and evening periods were devoted to demonstrations, conferences, field trips, recreation, entertainments, and the like.

The class instruction was supplemented by a large and carefully selected exhibit of the work of a number of country-life institutions.

Because of the very full schedule of required work and the distances between the College of Agriculture and the rooming houses, it was found desirable to house persons in attendance on the school in tents near the College; and this more or less informal " tent city " added much to the spirit and the unity of the school.

From the beginning, the School for Leadership has been considered a college enterprise and has been directed from the general administration office. In working out the plans for the school, invaluable assistance has been given by Fred M. Hill, State Secretary of County Work of the Young Men's Christian Association, and John R. Boardman, of the Good Will Home Association, of Hinckley, Maine. Some of the courses have been given by members of the regular staff of the College, and it has been necessary to call in also a number of specialists.

The faculty for the school of 1913 was as follows:

STAFF OF SCHOOL FOR LEADERSHIP IN COUNTRY LIFE

Officers

THOMAS FREDERICK CRANE, Litt.D., Acting President of the University
LIBERTY HYDE BAILEY, M.S., LL.D., Director of the College of Agriculture
GEORGE NIEMAN LAUMAN, B.S.A., Professor of Rural Economy and Head of the School for Leadership in Country Life
ALBERT RUSSELL MANN, B.S.A., Secretary and Registrar
ROYAL GILKEY, B.S.A., Instructor in Extension Teaching, in charge of exhibits

Faculty

JOHN R. BOARDMAN, B.S., Good Will Home Association, New York City. Lecturer on Rural Leadership
WILBERT L. ANDERSON, D.D., Amherst, Massachusetts. Lecturer on Rural Ethics
FRED M. HILL, State Secretary of County Work, Young Men's Christian Association, New York City. Lecturer on Rural Social Surveys and Community Programs
EDWIN L. EARP, Ph.D., Professor of Sociology, Drew Theological Seminary. Lecturer on Rural Sociology
THOMAS N. CARVER, Ph.D., Professor of Economics, Harvard University. Lecturer on Rural Economics
JESSIE FIELD, B.A., Secretary of Small Town and Country Work, National Board of Young Women's Christian Associations. Lecturer on Leadership for Farm Women
RALPH HICKS WHEELER, B.S., Assistant Professor of Extension Teaching, Cornell University. Lecturer on Extension Teaching in Agriculture
E. K. JORDAN, A.B., B.D., Secretary of County Committee, Young Men's Christian Association, Dutchess County. Lecturer on Rural Play
W. H. BAXLEY, County Work Secretary for Westchester County, Young Men's Christian Association. Lecturer on Rural Athletics
ALICE GERTRUDE MCCLOSKEY, A.B., Associate in Rural Education, Cornell University. Lecturer on The Farm Girl
MARTHA VAN RENSSELAER, A.B., Professor of Home Economics, Cornell University. Lecturer on The Farm Woman
FRANKLIN K. MATHIEWS, Chief Scout Librarian, Boy Scouts of America, Scotch Plains, New Jersey. Lecturer on The Farm Boy

EDITORIAL OFFICE

The general teaching, extension, and research work is visible and is well known to the casual observer. The mailing-room and editorial activities, however, are not evident except to one who takes the pains to inquire. Yet the editorial and publishing activities are probably some of the best indexes of the activities as well as of the complexities of the institution.

Of recent years the publication work of the College of Agriculture has increased very rapidly. The greatest increase in number of publications was occasioned in October, 1911, by the change in the organization of the Cornell Reading-Courses, whereby twenty-four issues instead of ten issues were published annually. In October, 1911, the monthly publication known as the Announcer was started, adding twelve additional issues in the year. With the enlargement of the staff of the College, the number of experiment station bulletins has also increased. In the year ending September 30, 1912, there were issued through the Editorial Office seventy-four completed publications, or an average of nearly one and one half a week. The total number of printed pages for that year was 4573. The total number of copies of completed publications printed was 2,122,415.

In the past year, a new series of publications to be known as memoirs has been started. These memoirs will provide a place of publication for many scientific papers that heretofore have been published in scientific journals. The memoirs are likely to be large publications, since they will

carry much of the detailed data accumulated in the course of the investigations that they present.

Prior to October, 1911, all the editorial work was handled by A. R. Mann, Professor of Agricultural Editing. On that date Miss Lela G. Gross was added to the staff as Assistant Editor, and has since given her entire attention to the editorial work in which she has shown great proficiency. In February, 1913, Miss Edith J. Munsell was engaged as an Assistant Editor, and has since given her full time to the editorial work.

Until the present, free-hand drawings for the publications of the College have been made chiefly by Professor W. C. Baker of the Department of Drawing. Mechanical drawings have been prepared by whatever persons the departments were able to engage for the work. It has been impossible for Professor Baker to give as much time to illustrating the bulletins as is desirable from the standpoint of the publications. It has been necessary to use half-tones instead of line engravings in many cases when the latter would have been preferable. We are now attaching to the staff Miss Clara L. Garrett as Artist in the Editorial Office. Miss Garrett is prepared to give attention to both free-hand and mechanical drawing. The entire editorial staff at present is as follows: A. R. Mann, General Editor; Lela G. Gross, Assistant Editor; Edith J. Munsell, Assistant Editor; W. C. Baker, Artist; Clara L. Garrett, Artist. It should be understood that Professors Mann and Baker give only part time to the editorial work.

There is a tendency on the part of many departments to submit to the Editorial Office for advice manuscripts that are not to be printed in the regular series of publications of the College, but that are to be published in scientific journals or are to be issued as publications of the particular departments. The Editorial Office is becoming a distinct department of the college work. The equipment of the office has been much increased during the past year and the facilities for efficient work are now practically complete.

Following is a summary of the work of the office from October 1, 1912, to September 30, 1913:

EDITORIAL BUSINESS FROM OCTOBER 1, 1912, TO SEPTEMBER 30, 1913

	Number of pages in printed bulletin	Number of copies ordered
BULLETINS:		
321 Computing rations for farm animals	36	30,000
322 The larch case-bearer	20	5,000
323 A study of feeding standards for milk production	68	6,000

	Number of pages in printed bulletin	Number of copies ordered
BULLETINS—*continued:*		
324 A study of the biology of the apple maggot (*Rhagoletis pomonella*), together with an investigation of methods of control	64	9,500
325 Cherry fruit-flies and how to control them	16	15,000
326 Water-soluble matter in soils sterilized and reinoculated	20	3,500
327 Methods of chick-feeding	52	40,000
328 Hop mildew	36	7,500
329 The fire blight disease in nursery stock	60	7,000
330 Respiration of fruits and growing plant tissues in certain gases, with reference to ventilation and fruit storage	36	7,000
331 The asparagus miner and the twelve-spotted asparagus beetle	28	12,000
332 Oriental pears and their hybrids	52	10,000
333 Control of two elm-tree pests	24	10,000
334 A study of some factors influencing the yield and the moisture content of cheddar cheese	28	10,000
335 Scab disease of apples	84	15,000
MEMOIRS:		
1 Some relations of certain higher plants to the formation of nitrates in soils	112	7,000
2 The action of certain nutrient and non-nutrient bases on plant growth	104	7,000
CIRCULARS:		
12 (Reprint) The chemical analysis of soil	4	6,000
13 Propagation of starter for butter-making and cheese-making	4	6,000
14 Working plans of Cornell poultry-houses	20	30,000
15 Legume inoculation	8	25,000
16 The improved New York State gasoline-heated colony-house brooding system	20	40,000
17 The formation of cow-testing associations	12	5,000
18 Milking machines: their sterilization and their efficiency in producing clean milk	12	15,000
19 Late blight and rot of potatoes	8	35,000
20 The fire blight disease and its control in nursery stock	12	15,000
READING-COURSE LESSONS FOR THE FARM:		
16 (Reprint) Practical dairy problems	......	12,000
26 Computing rations for farm animals	32	20,000
28 Recent New York State laws giving relief from taxation on lands used for forestry purposes	12	15,000
30 Hotbed construction and management	16	40,000
32 Composition of milk and some of its products	12	40,000
34 Home-garden planning	32	40,000
36 Culture of red and black raspberries and of purple-cane varieties	24	25,000
38 Principles and methods of plant-breeding	16	40,000
40 County, town, and village forests	12	20,000
42 Tilth and tillage of the soil	28	50,000
44 Methods of breeding oats	16	30,000
46 Feeding and care of the horse	20	40,000
48 Culture of the cherry	20	25,000
(12 discussion papers, 4 pages each)	48	

	Number of pages in printed bulletin	Number of copies ordered
READING-COURSE LESSONS FOR THE FARM HOME:		
25 Saving strength	16	35,000
27 Choice and care of utensils	24	40,000
29 Cost of food	12	40,000
31 Household bacteriology	20	40,000
33 Vegetable-gardening	28	50,000
35 The flower garden	20	40,000
37 Home economics at the New York State College of Agriculture	32	45,000
39 The farmhouse	32	50,000
41 Rules for planning the family dietary	12	50,000
43 The box luncheon	12	45,000
45 Hints on choosing textiles	12	45,000
47 A canning business for the farm home	8	45,000
(11 discussion papers—none for No. 37)	30	
RURAL SCHOOL LEAFLETS:		
November, 1912	16	150,000
January, 1913	20	150,000
February, 1913 (Agricultural contests)	96	30,000
March, 1913	32	175,000
September, 1913	212	55,000
ANNUAL REPORT FOR 1912	1,867	2,000
ANNOUNCER:		
October, 1912	4	55,000
November, 1912	4	48,000
December, 1912	4	49,000
January, 1913	4	60,000
February, 1913	4	70,000
March, 1913	4	58,000
April, 1913	4	60,000
May, 1913	4	100,000
June, 1913	4	64,500
July, 1913	4	60,000
August, 1913	4	70,000
September, 1913	4	65,000
ANNOUNCEMENTS:		
Department of Forestry	20	7,000
Summer School	24	7,000
Regular Announcement of Courses	66	20,000
Winter Courses	34	10,000
School for Leadership in Country Life	16	1,500
Handbook of Information for Students	32	1,300
Winter Course Circular	4	5,000

Work handled during September, to be printed after September 30

BULLETINS:		
336 Distribution of moisture and salt in butter	*24	8,000
337 The Babcock test, with special reference to testing cream	*24	15,000
RURAL SCHOOL LEAFLETS:		
November, 1913	28	200,000

* Estimated number of pages.

Summary

	Total number	Total pages	Copies printed
Experiment Station bulletins	15	624	187,500
Experiment Station memoirs	2	216	14,000
Experiment Station circulars	*9	100	177,000
Reading-Course for Farm	*13	240	397,000
Supplements to Reading-Course for Farm	†12	48	‡397,000
Reading-Course for Farm Home	12	228	525,000
Supplements to Reading-Course for Farm Home	†11	30	‡480,000
Rural School Leaflets	5	376	560,000
Announcers	12	48	759,500
Annual Reports	1	1,867	2,000
Announcements	7	196	51,800
Publications handled during September, to be printed after September 30:			
Bulletins	2	§48	....
Rural School Leaflets	1	28	....
Grand totals	79	4,049	2,673,800
Plus supplements omitted, as indicated above	23		877,000
	102		3,550,800

* One reprint.
† Not counted in grand total number of separate publications issued.
‡ Not included in grand total of copies printed, as printed with the bulletin.
§ Estimated number of pages.

OTHER ITEMS

A significant recent development in country-life work is the rapid establishment of farm bureau agencies. The College of Agriculture is not directly concerned in the organization of these agencies, but it is glad to aid them and to cooperate with them on the educational and scientific side. As a result of cooperation between the United States Department of Agriculture and the College, a supervisor, or leader, of the farm bureau work has been established at the College of Agriculture, in the person of Lloyd S. Tenny. Mr. Tenny not only has charge of the farm-bureau work itself under the auspices of the United States Department of Agriculture, but also is to be a part of the regular staff of the College and to maintain a supervisory relation with former students in respect to their farming operations. Seventeen counties in New York now have organized farm bureaus. These bureaus have administrational relations with the United States Department of Agriculture and the State Department of Agriculture, and educational relations with the College of Agriculture.

The College itself, through its Extension Department, has many representatives or agents in the different counties, who are to advise the insti-

tution as to the needs of the localities and who take part in the organization of local extension enterprises.

The former Department of Horticulture has now been divided into three more or less natural units. One of these units is pomology, which was separated some years ago. At present the floriculture and the vegetable-gardening are being separated as coordinate departments. This means the enlargement of the floricultural and vegetable-gardening work, and expresses the desire of the College to serve adequately these great interests in the State.

Several new professors have recently been added to the staff. W. H. Chandler, of the University of Missouri, becomes a Professor of Investigation in the Department of Pomology; F. B. Moody, of Wisconsin, becomes Extension Professor in the Department of Forestry, giving that department four full professors and one assistant professor. K. M. Wiegand, of Wellesley College, takes charge of the new Department of Botany, in which a large staff is now provided. A number of the assistant professors have been promoted to full professorships. The total number of full professors in the College of Agriculture, devoting themselves exclusively to its work, is now above forty.

We greatly regret to have lost the services of Dr. H. J. Webber, who has been called to the new work in California. Doctor Webber came to the College with an established reputation as an investigator and plant-breeder, and has given the institution many years of spirited and devoted service. He leaves the Department of Plant-breeding with a high reputation.

The physical establishment has seen marked improvements within the year. The farms, some of which are recent purchases, are now beginning to show change. Large areas are devoted to special interests. About eighty acres, for example, is devoted exclusively to poultry husbandry. Large areas have been set aside for the fruit-growing, floricultural, and vegetable-gardening work. A farm is devoted to field investigations. A crop garden has been established. A number of minor buildings have been erected or improved on the farms. The dairy business has been extended. The College now owns four creameries or milk stations, covering a territory some twenty miles to the rear of the institution. The Department of Dairy Industry draws milk from more than twelve hundred cows.

The grounds are beginning to take shape, although there is not yet any proper road access to the College of Agriculture either from the main campus or from the public highways. Several new buildings are under way and under plan. The ten-years plan adopted some years ago by the Board of Trustees is probably at present about half completed. This plan must be speedily brought to a conclusion if the College is to be able

to handle effectively the increasing numbers of students. I am convinced that the general plan as outlined, with such necessary extensions as develop in the meantime and with a properly increased staff, will enable the institution to handle with efficiency and success more students than it now has.

Respectfully submitted,

L. H. BAILEY,

Director New York State College of Agriculture.

W. A. STOCKING, JR.,

Acting Director New York State College of Agriculture.

STATEMENT OF STATE MAINTENANCE APPROPRIATION

1912–1913

October 1, 1912. Appropriation, $265,000.
Expended as follows:

Plant-breeding	$ 1,889.72
Drawing	182.93
Farm Practice	14,199.07
Pomology	2,823.52
Home Economics	2,006.56
Forestry	1,739.75
Landscape Art	1,592.21
Animal Husbandry	10,686.13
Entomology	3,012.74
Plant Pathology	1,590.19
Nature Study	227.38
Plant Physiology	3,433.60
Rural Economy	146.10
Library	392.57
Meteorology	29.25
Chemistry	962.49
Horticulture	3,195.53
Farm Management	2,337.01
Farm Mechanics	2,690.00
Dairy Industry	11,511.13
Soil Technology	1,381.40
Poultry Husbandry	7,948.44
Administration	49,727.75
Salaries	141,294.53
Total	$265,000 00

No unexpended balance after September 30, 1913.

EXTENSION WORK

October 1, 1912. Appropriation for extension work, $50,000.00.
Expended as follows:

Plant Pathology	$ 1,052.16
Rural Economy	76.82
Entomology	75.36
Administration	2,525.77
Pomology	1,191.85
Horticulture	428.36
Dairy Industry	1,027.94

Farm Management	$ 1,375.58
Plant-breeding	698.51
Animal Husbandry	800.54
Home Economics	1,638.87
Rural Education	1,470.16
Soil Technology	2,186.61
Poultry Husbandry	1,685.58
Farm Practice	1,846.59
Extension Teaching	9,955.66
Salaries	21,963.64
Total	$50,000 00

No unexpended balance after September 30, 1913.

EXPERIMENT STATION FUNDS

July 1, 1913

	Received	Expended
Hatch	$13,500	$13,500
Adams	13,500	13,500

Expended as follows:

	Hatch	Adams
Salaries	$6,218.27	$6,753.23
Labor	3,951.57	4,817.34
Publications	131.85	....
Postage and stationery	911.43	134.75
Freight and express	175.13	14.32
Heat, light, water, and power	369.44	....
Chemicals and laboratory supplies	214.32	541.96
Seeds, plants, and sundries	311.72	245.08
Fertilizers	91.37	29.00
Feeding stuffs	77.68	....
Library	27.06	76.56
Tools, machinery, and appliances	214.90	110.21
Furniture and fixtures	112.74	330.67
Scientific apparatus and specimens	150.00	....
Live-stock	100.00	....
Traveling expenses	267.95	72.91
Contingent expenses	20.00	....
Buildings and land	154.57	373.97
Total	$13,500.00	$13,500.00

No unexpended balance after September 30, 1913.

January 23, 1914

W. A. STOCKING, Jr., *Acting Director, College of Agriculture, Cornell University, Ithaca, New York:*

SIR:— In accordance with the instructions received through your general office we have made a detailed audit and examination of your books and accounts for the fiscal year beginning October 1, 1912, and ended September 30, 1913, both inclusive, and as a result submit herewith financial statement showing receipts of all moneys by your office from the various departments, and deposited with the University Treasurer.

For your convenience we have made an analysis of these receipts, showing the cash received from each department.

We have verified these amounts as entered on your cash book, with the duplicate copy of the original receipt as given to the department making such deposit, and we have further satisfied ourselves as to the accuracy of same by comparing these amounts with the entries made on the books of the contributing departments.

We have also checked the postings from your cash book to the respective accounts on the general ledger, and can certify that each department has got full credit for same. We have verified all footings and found same to be correct.

We have also verified the amounts credited on the personal accounts (for goods purchased from the several departments) and have found in every case that a corresponding entry has been made on the cash book, that the money has been actually received and later deposited with the University Treasurer.

In further corroboration of this, we have compared the amounts as shown on the cash as being deposited with the Treasurer, with the amounts as entered on the books of the Treasurer's Office, and can certify as to the correctness of same.

We have counted the cash in the hands of your clerk and bookkeeper and find same to agree with the balance, as shown on the cash book.

We have made several suggestions to your clerk as to the details of your bookkeeping, which will greatly facilitate matters in the event of reference to any of the accounts.

We desire to say that every facility has been afforded to us, in order to make this audit as complete and thorough as possible, and we are of the opinion that the statement attached hereto represents the actual cash received from all sources during the period.

We have pleasure in testifying that we found the books in first-class order, the entries being neatly and correctly recorded, and considering the large amount of detail work in connection with your office, is an evidence of care and attention on the part of your bookkeeper.

Respectfully submitted,

NATIONAL AUDIT COMPANY,

(*Signed*) GEORGE WATSON,

Certified Accountant.

DEPARTMENT OF FARM MANAGEMENT

TEACHING

The total number of students taking work in this Department during the year 1912–1913 was as follows:

Course	Subject	Term	Number of students registered
1	Farm Management	1	204
1	Farm Management	2	154
3	Advanced Farm Management	1	36
4	Research	1	2
5	Seminar	1	27
5	Seminar	2	14
Graduate students		1	16
Graduate students		2	18
Winter Course 17		......	98
Winter Course 18		......	51
Summer School, course C		......	8
Summer School, course B		......	13

Besides the graduate work, a total of 1544 student hours of instruction was given. The number of instructors is too small for the number of students.

INVESTIGATION

The chief lines of investigation are as follows:

1. The agricultural surveys of Livingston and Jefferson counties are not yet completed.

2. The Department is continuing to study the most successful farms that are found by survey methods. The study includes not only those that are the most successful of all, but also those that are the most successful under special conditions, such as successful farms with small capital and successful farms on unfavorable soil types. Successful tenants are studied as they change to new farms, and the records of the old farms are obtained under the different management. The Department hopes to continue this work permanently. The work is being done by Professor Livermore.

3. The study of the cost of producing milk in Delaware county is being continued by Mr. Thompson. In order to obtain results in a year with

different food prices, the same farms were again visited in the summer of 1913 and records were obtained.

4. The work begun three years ago in keeping complete sets of cost accounts on some farms is being extended. This year such accounts are being kept on over fifty farms. During the past two years the work has been done in cooperation with the United States Department of Agriculture. Mr. Ladd has charge of the work.

5. The cost of producing potatoes is being studied by the survey method. For this investigation 335 records were obtained on Long Island and 362 records in Steuben county. The Department of Farm Crops is cooperating in the work and is studying methods of growing potatoes.

EXTENSION

The investigative work mentioned above, particularly that in cost accounts, is also extension work. The Department has sent representatives to some farm meetings and has answered many letters from farmers.

RECOMMENDATIONS

The most important need at present is additional teaching force, and one or two professors to devote their entire time to extension work.

G. F. WARREN,
Professor of Farm Management.

DEPARTMENT OF FARM PRACTICE AND FARM CROPS

TEACHING

Teaching in farm practice during the past year was confined to that given the winter-course students, of whom there were 260 registered.

In farm crops instruction was offered in eight courses. All this instruction was given by Professor Montgomery, with assistance in the laboratory work. The total number of undergraduate students was 300, with 1112 credit hours; there were 8 graduate students.

INVESTIGATION

The following investigative work has been undertaken in connection with the demonstration garden:

Relation of time and frequency of cutting on yield and duration of forage crops.— For this test fourteen of the common grasses and clovers have been sown in plats. A part of each plat will be cut as hay, and a part will be cut frequently as though under pasture. Four principal observations will be made, as follows: (1) effect of each treatment on the life of the sod; (2) period of maximum production under each treatment; (3) total production of dry matter under each treatment; (4) variation in production during the season.

Another series of plats will be manured each year, and a third series will be fertilized. The same observations will be made on these series as on the first.

Nurse-crop experiment.— This experiment was made in order to determine the direct effect of the nurse crop on the seeding. Oats and barley, sown at different rates, are used as nurse crops, and alfalfa, red clover, and timothy are used as seeding.

Lawn grasses and mixtures.— In connection with establishing demonstration plats, studies will be made of the principal turf grasses.

Demonstration and economic garden.— The experiments outlined above are being made in this garden, and are to be regarded as demonstration work as well as experiments. Other demonstration work is planned. A beginning has been made toward a collection of economic plants and their relatives. It is planned to make this garden a field laboratory, supplementary to the teaching work. The garden will be of particular value in the summer course.

EXTENSION

The principal extension enterprise of the Department has been the potato survey. The proposed plan is to conduct a survey in each of

the five or six principal potato-growing regions in New York State. During the past summer 335 records were taken on Long Island, and 362 from the Steuben-Livingston-county region. Some attention is given to the formation of a potato-growers' association.

Additional extension work during the year consisted in the attendance, by Professor Stone and Professor Minns, at eight extension schools; attendance at eight meetings; and personal visits to eight farms. The correspondence of the Department has continued very heavy throughout the year; and the bulk of this correspondence is distinctly extension work, answering questions from the farmers of the State.

RECOMMENDATIONS

Farm practice

The improvement of the farms continues, and more work in farm drainage and the clearing of hedgerows has been done this year than for several years past. The limiting factor in this kind of work in the past has been available teams. Men can always be found to do the hand work, but the Department cannot undertake jobs for which it cannot furnish team work. This work is at its height at the end of the fiscal year, extensive jobs being under way. It is therefore impossible to state the exact number of rods of drains that have been laid or of hedgerows that have been cleared.

Regarding land, with the area rented the College has land enough to meet its requirements fairly well. Some of the rented land should be purchased when it comes on the market, and there are two or three pieces of land, not rented, which, owing to their location, should be procured when it is possible. The Department is in no hurry to acquire this land, because at present there is plenty of improvement work to be done on the land that it already owns.

A matter that has caused considerable difficulty is the finding of living accommodations for the farm laborers. More cottages are needed, also a large, roomy boarding house. In order to meet the latter need, the Button house, in Forest Home, has been rented and here accommodations have been provided for some of the men. There are two reasons for this need: first, the teamsters must be located near enough to the barns to allow of their going there to do some of their chores before breakfast and after supper; second, living expenses are so high in Ithaca that, while the College is perhaps paying more than the usual rate of farm wages, the men who pay their board are not able to save from their wages as much as the ordinary farmer pays them with board and room furnished. The College must either manage to furnish the men cheaper accommoda-

tions, or else increase their pay. Increasing the pay, however, would not solve the question of nearness to the barns. The Department is therefore trying the experiment of furnishing the men with accommodations near by, with the hope of making the expense less.

Farm crops

At least two additional full professors are needed in the Department, in order that present needs may be adequately supplied. No adequate graduate work can be developed without more help in teaching. The extension work among farmers must wait until a qualified man can be employed for this particular work. With the development of the demonstration and economic garden, a competent man is needed for field work.

Practically no suitable land is assigned to the Department at present for experimental work. A few acres should be assigned soon, and steps should be taken to provide more land in the future; in time fifty or sixty acres will be needed. The Kline farm, north of Beebe Lake, would be very desirable if it could be acquired.

A good field house is needed, with a cellar for root storage. Such a house should have a fireproof section for the storage of valuable seeds.

In connection with the economic garden, a small greenhouse and a set of cold frames should be provided.

In time a Skinner irrigation system should be provided for a part of the garden, so that good specimens can be grown in dry years.

THE COLLEGE FARMS

The New York State College of Agriculture has 766 acres of land and rents 150 acres additional, making a total of 916 acres under college management. These farms are run, not for commercial, but for educational, purposes, and the practices are therefore modified so as to meet the varied demands of the institution.

Land in the vicinity of the College is very broken, abounding in hills and dales, brooks and gorges. In consequence, less than one half of the total area is now available for tillage. Of the 916 acres, 508 are classified as arable, 188 as pasture, and 133 as wood and waste, 48 are devoted to college campus, buildings, and old orchards, and 39 are retained for other uses.

Of the tillable area, 45 acres have been laid out in permanent experiment plots for the use of the departments of Soil Technology and Plant-breeding; 50 acres have been assigned to the Department of Pomology and are largely planted to young trees; 45 acres have been assigned to the Department of Horticulture; 73 acres to the Department of Poultry Husbandry; 9 acres to farm-crops garden and experiments; and there

are left to the Department of Farm Practice and Farm Crops 286 acres on which to conduct the regular farm operations.

The soil of the college farms is heavy, nearly all of it being Dunkirk clay loam. A few fields at the extreme southeastern corner are Volusia stony loam. The Dunkirk clay loam is entirely unsuited to potatoes and is not well adapted to corn, but will grow fair crops of corn if heavily manured. It is well adapted to wheat, oats, timothy, and clover. The Volusia stony loam is well adapted to corn and potatoes when well drained and freed from stones. The recently acquired areas lack both these improvements.

In order that they may be readily accessible from the college buildings, the principal barns have been located at the extreme western end of the large farm domain. This entails a very long haul for a large part of the farm crops and of the manure, entailing a heavy labor cost.

In planning the cropping scheme, or rotations, for the farms, three considerations have been kept in view — the soil adaptation, the long haul, and the forage requirements of the live-stock. Fortunately, these considerations harmonize in the main. The heavy soil and the long haul make the growing of the desired amount of corn for silage a difficult task. It is on this point that the rotations hinge. The needed silage cannot be purchased elsewhere. A surplus of silage or corn fodder could not be disposed of. Sufficient silage corn is grown, and, so far as possible, within easy hauling distance of the barns. Besides the corn, the farms raise oats, wheat, clover, timothy, and potatoes, because they are adapted to the soil and are needed at the barns or are of ready sale.

In planning the rotations, twenty-three fields are divided into five groups. The first group, comprising fields numbers 6, 7, 8, 11, and 12, is located convenient to the silos and therefore should be made to produce as much corn as is practicable. This land is in corn two years out of five. The rotation is: first year, corn; second year, corn; third year, oats; fourth year, wheat; fifth year, clover. The purpose is to grow the first crop of corn on the clover sod without manure; to sow in the corn at the last cultivation a catch crop of rye, manure to be applied, and both it and the rye plowed down for the second crop of corn. Timothy seed is applied in the fall with the wheat, and clover in the spring. The corn stubble is plowed in the fall, so as to be ready for the early sowing of oats. The oat stubble is broken immediately after harvest, so as to give as long a time as possible for fitting the land for wheat.

The second group is composed of four fields, numbers 3, 4, 16, and 17. Two are near the barns and two are rather remote. On these fields the rotation is corn, oats, wheat, and clover. This land bears corn once in four years.

The third group comprises fields numbers 10, 20, 22, 23, and a combination of 21 and 24. These fields are so remote from the main barns as to make the hauling of silage from them expensive. No more corn is grown on them than is necessary. It is found that a crop of corn on this land once in five years will probably meet the requirements. The rotation adopted, therefore, is: first year, corn; second year, oats; third year, wheat; fourth year, clover; fifth year, timothy.

The fourth group comprises fields numbers 51, 52, 53, 55, and 56, on the southeast farm. This farm is so far from the main barns that the hauling of silage is prohibitive. This land, therefore, is devoted as fully as possible to the production of hay. It is planned to break this land after haying, fit and sow to winter grain or oats, seed back to timothy and clover, and mow for four years. Manure may be applied as a top-dressing to the grass or when the land is broken. Nitrate of soda may be used in order to increase the yield of timothy. This rotation is still in the experimental stage. If it is found that a field of corn is desired for grain and dry fodder, corn can be grown when the land is broken.

The fifth group comprises fields numbers 57, 58, and 59. These fields are practically the only ones on the college domain that are at all well adapted to potato-growing, and these are not in satisfactory condition for this use because they are very stony and water seeps from the hill to the south and keeps them wet for a long time after wet weather. Drainage and clearing will correct this.

A short rotation — first year, potatoes; second year, oats; third year, clover — has been adopted for this group. It is the practice to plow the sod in the fall for rye, apply manure during the winter, and plow down for potatoes in the spring. This gives a well-rotted sod and additional organic matter.

It is desired to call attention to the fact that, while such a cropping scheme may seem rather ironclad and not suited to variable needs, it really is very adaptable. If it is found that the rotations give more corn than is desired, the sod field in the first group that is due to be broken for corn may be mowed a second time, thus giving two crops of hay instead of two crops of corn. Or, if it is found that the area of corn must be increased, part of the land in the third group may be broken after mowing once instead of after mowing twice, and be made to grow two crops of corn in five years instead of one. If very short of hay and no corn area can be spared, wheat may be dropped out of the rotation and the seeding done in the oats, and thus an extra year of hay on the land may be gained.

If, owing to a very wet autumn, it is impossible to do the usual wheat seeding, as sometimes happens, the area intended for wheat may be sown to oats in the spring and the meadow seeds added at this time.

If a piece of roots or cabbage is desired, it may be given a small area on the land that is to grow corn for the second time. None of these variations disarrange the general cropping scheme in the least.

While a large number of crops are not grown in the farm rotations, field number 5 has been set aside as a farm-crops garden and demonstration area. Here every crop that can be grown in this region will be planted and demonstrations of cultural methods will be made.

Owing to variations in the size of fields the annual planting of the several crops will vary somewhat; however, the following is about what the average areas will be:

Potatoes	7 acres	Roots	3 acres
Corn	44 acres	Clover	55 acres
Oats	50 acres	Timothy	48 acres
Wheat	34 acres	Alfalfa	30 acres

The cropping scheme described above is not yet fully in operation. The following are the areas planted and the production for 1912:

	Acres	Products (as far as harvest is completed)
Corn	58	387 tons silage
Oats and peas	7	36 tons silage
Oats	34	1,943 bushels
Wheat	4	100 bushels
Clover	46	318 tons
Timothy	60	
Alfalfa	29	102 tons
Rye	4	
Meadow seeding	21	(No nurse crop)
Roots	2	55 tons
Cabbage	½	
Soy beans	½	
Farm-crops garden	1	
Potatoes	4	1,000 bushels

J. L. STONE,
Professor of Farm Practice and Farm Crops.

E. G. MONTGOMERY,
Professor of Farm Crops.

DEPARTMENT OF PLANT-BREEDING

TEACHING

The work of instruction has continued to grow very rapidly during the past year. Over two hundred persons were registered in the undergraduate courses, and a strong tendency was observed toward a much larger registration in the advanced courses. Many more students are specializing in plant-breeding than has formerly been the case.

Instruction to postgraduate students also has gradually grown. The demand has increased much beyond the capacity or the facilities of the laboratory. The Department is more and more cramped for space. Many agricultural colleges throughout the country have granted leave of absence to their teachers or investigators in plant-breeding, in order that they may spend a year or more in our laboratory.

A much closer cooperation has been perfected with other departments teaching the various phases of plant industry and also of breeding.

RECOMMENDATIONS

The Department wishes to repeat, with renewed emphasis, the requests of the past. The great increase in registration of students makes relief absolutely necessary. Greater laboratory space must be provided in order to accommodate the students.

The immediate establishment of an arboretum and a botanical garden is urged. For purposes of instruction and investigation there should be a large collection of native and foreign plants, for use in various ways in breeding work.

It is recommended that funds be set aside for engaging nonresident lecturers to give lectures on genetics. This field is so broad and so technical that, in order to make it complete, parts of the instruction should be given by specialists. The large number of postgraduate students gathered from all over the country should have an opportunity to come in touch here with specialists in the various phases of genetics.

A plan was projected by the former head of this Department, by which postgraduate students in genetics from Harvard and Columbia universities could study here for one semester during the three-years study for the doctor's degree, and our students could study at either Harvard or Columbia for an equal time. This would give the students a breadth of training and a different point of view. The Department believes this to be a good plan, and wishes to forward it to completion.

The Department recommends also greater facilities for graduate and undergraduate work in genetics; greater laboratory and greenhouse space; better library facilities; and greater funds with which to make more efficient the work of the Department.

ARTHUR W. GILBERT,
In charge of instruction.

INVESTIGATION

Experiments in breeding timothy

The timothy-breeding experiments, begun in 1903, are still in progress and are still productive of interesting results. During the course of this investigation more than two hundred and fifty types, or varieties, of timothy have been isolated. The majority of these are still in the experiment and furnish excellent material for study. There have been two aspects to this piece of investigation, the scientific and the practical.

From the scientific standpoint, the study of the various types as to the transmission of different characters continues to be of interest. Many of these types have now been under observation for a period of seven years. Notes are being kept of the development of individual plants during their entire life history.

Statistical data of the most widely varying sorts are being kept, and sufficient of these are now on hand to justify a biometrical treatment for the purpose of definitely describing the different kinds. In this connection the study of the correlation of various characters will be of value, and such a study can be made from the above data.

During the progress of the experiment many clonal propagations have been made from individual plants. There has been some indication that bud variation occurs in some of these instances. Careful propagations have been made for the purpose of studying this point, but the plants have not yet developed sufficiently to obtain definite results.

It has been clearly demonstrated that in some crops, especially corn, there is a decrease of vigor when strains are purified by inbreeding, but that this vigor is readily regained by cross-breeding of different pure strains. Timothy, being an open-fertilized plant, may be analogous to corn in this respect. As stated above, many different strains of timothy have been isolated. Although these are not pure in the sense of the pure-line theory, they are pure for many of the grosser characters. It is a question whether or not this purification by inbreeding decreases the vigor. In order to furnish evidence on this question, five of the best strains have been planted together in a composite bed. The seed from this bed will be grown, and the plants will be compared with those produced by seed from the same so-called pure strains.

The old broadcast test plats, sown in 1908 to the most promising strains in comparison with the best available commercial seed, were plowed this year soon after the hay had been cut. Such action was necessary because of an exchange of land between this Department and other departments. From this series of plats, which had been grown for four years, some gratifying results have been obtained. In this test there were originally seventeen new varieties compared with seven check plats

of the commercial seed. One of the plats was destroyed by a road, leaving sixteen of the new varieties in the test. From these sixteen new varieties, the average gain for four years of the five best over their checks has been 2100 pounds per acre; five others have given an average increase of over 1000 pounds per acre, five others have ranged between 284 and 975 pounds per acre increase, while only one was inferior to the check. The above varieties have been repeated, together with a large number of other promising varieties, in fortieth- and eightieth-acre plats. These will be continued for several years before final conclusions can be drawn.

The distribution of seed begun in 1912 has been continued this year, so far as the amount of seed available would allow. In addition to this, there are in progress fourteen cooperative experiments in different parts of the State for the purpose of testing the new varieties further and increasing the seed. Thus the seed is being increased as rapidly as possible, and it is expected that the best varieties will soon be available in commercial quantities.

Experiments in breeding corn

The corn-breeding experiments that have been conducted by this Department have been continued as in preceding years, with one exception which will be noted later As noted in previous reports, the corn-breeding has been conducted by the ear-to-row plat method. Plats of Pride of the North at Aurora and Funk's Ninety Day at Ballston Lake have been under way for six years. A change was made in the method at Ballston Lake for 1913. This plat was not planted by the ear-to-row method, but the best progenies were mated and grown there and selections were made from these. At Bedford Hills also an experiment in the selection of Funk's Ninety Day is being conducted, having been started in 1910 from seed from the plat at Ballston Lake.

The main object of these experiments is to obtain strains of dent corn that will mature under New York conditions and will also give a high yield of grain. These different strains are responding very markedly to the selection for earliness. The effect of this selection is well illustrated by the results of a test made at Ballston Lake: A composite sample of select seed was obtained by taking a small quantity of seed from each of the ears which were to be planted in the breeding plat. In order to compare the gain in earliness, rows of this seed were planted alternately with rows of the original unselected seed. The crops from these alternate rows were harvested and were carefully compared with reference to earliness. It was found that the crop harvested from the selected seed gave seventy-two per cent of ripe corn, while that from the unselected seed gave thirteen per cent of ripe corn. This difference in degree of ripeness

represents a gain of at least two weeks in earliness of maturing. As stated before, productivity has been kept in mind in these selection experiments, so that the earlier strains remain fully as productive as the original variety for New York conditions.

A matter of importance in connection with these experiments is, whether the new strains that are earlier and will mature seed will be of as great value for silage purposes as those varieties that require a longer season, thus naturally producing larger stalks and usually not such a high percentage of grain. In order to obtain some data along this line an experiment was begun, the purpose of which is to compare one of these early strains with some of the common commercial varieties that are grown for silage. This experiment was begun in 1911 and is still being continued. It is important to know whether it is possible to obtain a variety that will be a good producer of silage as well as of grain. Many notes have been taken on the parent ears in order to learn whether there are any visible seed-ear characters that may indicate either high yield or earliness. These experiments have not as yet been completed. A preliminary paper has been published on this subject, but additional data are being collected.

A distribution of seed of some of these sorts was made during the past year. Usually only a small amount of seed was sent, so that the farmer could compare this with the corn that he had been accustomed to growing.

Experiments in breeding potatoes

The potato-breeding work was begun in 1908. It was designed primarily for a scientific study of variation and of the effect of selection within pure-tuber lines. From the practical standpoint it has thrown light on some of the methods of potato selection.

The experiment has not been conducted sufficiently long to warrant the publication of many definite conclusions. However, some interesting and suggestive observations have been made. It might be expected that the offspring of a single parental tuber, propagated by cuttings, would be uniformly true to the parental type. This seems to be true to a certain extent. The pure-tuber lines are remarkably uniform in regard to habit of growth, vigor, yielding capacity, shape and color of tuber, and the like. But within these pure-tuber lines there have occurred variations pronounced and definite enough to constitute a new line, and the progeny of this line has continued true to the new type. In this manner there have been isolated a good-yielding, a medium-yielding, and a poor-yielding strain, all from the same pure line. This kind of variation has occurred also with respect to the shape, size, and color of the tuber.

In this experiment a comparison has been made between the apical (seed) and the basal (stem) end of each tuber. It has been observed that

a large number of the low-yielding, or degenerate, strains have sprung from the basal cuts. To draw a practical comparison, in a test of twenty-two varieties for two years the apical hills gave an average yield of one hundred and eighty bushels per acre, while the basal hills yielded one hundred and fifty-one bushels.

More data will be accumulated in regard to the amount and nature of the bud variation within these pure lines. The results given here can be considered only as preliminary. Several years more must elapse before any definite information will be available concerning the accumulative effect of selection within a pure line.

From the practical standpoint the experiment has justified the method of hill selection for the improvement of potatoes. Although these offshoots of varying types occur, probably they are infrequent enough to be of little consequence to the grower who is practicing hill selection. As an example of this, the four-years average of selections from three low-yielding strains is 93.8 bushels per acre as against 231.3 bushels per acre for the selections from three high-yielding strains. Several promising strains have been isolated; these will be tested in comparison with commercial varieties, and if they prove superior they will be distributed for general use.

Experiments in breeding cereals

The investigations in cereals conducted by this Department comprise experiments with oats, wheat, barley, and buckwheat. The experiments with oats and wheat are conducted in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture.

Oat-breeding experiments.— These experiments are divided into two or three different lines. One of these lines, the testing of a large number of hybrids and selections that have been made from some of the commercial varieties of oats, has been continued during the past year much the same as reported in previous years. These hybrids and selections have been carefully compared with the commoner commercial varieties in order to determine their value. The tests have been conducted by what is known as the rod-row system, and each strain, or variety, has been repeated ten times. The average of the ten test rows, therefore, represents the yield for each variety. The yield of straw, as well as that of grain, has been taken for the past three years. Other notes, such as height of straw, date of ripening, and the like, have also been taken. Some of the new strains have given promise of being of value for further testing and distribution, and a number of them have been sent out to different parts of the State for this purpose. Two in particular, an early and a late selection, have been distributed in about fifty different places. The

results from these test plats have not all been assembled, so that no report can be made on them at this time.

A number of new varieties of oats from Canada, France, and Sweden have been brought into the test during the past year.

During the summer of 1912 a large number of new individuals were selected from some of the best commercial varieties. These were grown for the first time in 1913. A number of them show promise of being good sorts, both as to yield of grain and stiffness of straw; these are being saved for planting in larger plats another year. Each of these individual selections has been carefully compared with the variety from which it was selected, and those that gave better results than the varieties will be used for future work.

For the past two or three years many new hybrids have been made — first, in order to obtain some better-yielding types suitable for New York conditions; and second, in order to study the inheritance of the different characters of oats, so that more light may be thrown on the proper methods of breeding this crop.

Wheat-breeding experiments.— These experiments have been continued in much the same manner as has been outlined in previous reports, with the exception that many of the selections have been discontinued and only those that have shown superior worth are being tested in comparison with a large number of commercial varieties. This testing has been conducted in the same manner as with the oats; that is, the rod-row system is being used and each strain, or variety, is being repeated ten times. Notes are being taken on such points as height, date of ripening, yield of grain, and yield of straw. The work has progressed far enough to show that there are a number of selections that give much better yields than do the varieties from which they were selected.

As mentioned in previous reports, several hundred new head selections were made from some of the better commercial varieties, and these were sown in the fall of 1912 and harvested in 1913. A number of them showed promise; these have been saved and planted in larger plats this year, in order to give them a further test. In each case the selection is compared directly with the commercial variety from which it was selected. During 1913 a number of head selections were again made, and these have been sown in head-rows this fall.

Selections are being conducted also in connection with the Shredded Wheat Company, in order to obtain some high-yielding strains of wheat suitable for the use of that company. This work is being done in the western part of the State, since that section is well adapted to the growing of the particular kind of wheat desired by the company.

A number of samples of wheat have been sent out this year to farmers for further testing. These are cooperative tests, and the farmer grows a plat of his own wheat in comparison with these new sorts.

Some of the better strains of wheat that have been under test for the last several years are now being grown on increase plats, with the hope of obtaining some seed for distribution and also in order to give these strains further test under field conditions.

In the past year a large number of wheat hybrids have been made, with the hope of obtaining some strains of good commercial value combining both quality and winter resistance.

Barley-breeding experiments.— During the summer of 1913 a large number of commercial varieties of barley were grown, in order to obtain results showing the more promising sorts for New York conditions. When these results are obtained, breeding work will be begun with the most promising sorts in an attempt to obtain some better strains of barley for commercial growing.

Buckwheat-breeding experiments.— A number of varieties of buckwheat were grown in 1913 for the first time, in order to obtain evidence as to which types are better adapted to New York conditions and also to obtain material for making selections looking to the improvement of the yield and the quality of the crop. A number of plants have been selected. These will be grown, and the better ones will be increased in order to start a further test in comparison with the commercial varieties from which they were selected.

Forage-crop investigations

Little work has been done in forage-crop investigations, with the exception of some brome-grass selections. A number of strains of brome grass have been isolated and these are being studied with reference to their possible value as forage plants.

It was planned to begin clover investigations this year, but, owing to the change in the staff of the Department, it was not possible to take up this work. Seed has been collected from a number of places and it is hoped to get the investigations under way very soon.

Adams Act research

The work on projects under the Adams Act has been continued in accordance with the plans outlined in previous reports, with the exception of the investigation on peppers; this will be completed by Doctor Webber in California.

Studies on variation.— At the beginning of the work of this Department, variations and their causes seemed to be very important. With this in

mind a number of problems were begun on the subject. These problems may be divided into two general heads — the measurement of variations as they occur naturally, and the effect of food supply, temperature, and the like, on the production of variations.

General variation studies have been under way for some time on wheat, oats, barley, and asters. In addition many data have been collected on the common field daisy. Here the amount of variation occurring normally in different habitats has been carefully studied, as well as the change of type throughout the blooming season of the plant.

The studies on the effect of food supply have been under way since 1908. One bulletin and a short paper have been published, and Doctor Myers, who is continuing the work, will shortly have material for publication.

Studies on the laws of inheritance.— The studies with hybrids have been continued and many data have been obtained from experiments with tomatoes, phlox, peppers, and the like. In the work with tomatoes and peppers, the inheritance of quantitative characters, as well as of qualitative characters, has been considered.

Mendelian studies are being made also with oats, wheat, radishes, morning-glories, and other plants, and data of considerable interest are being accumulated.

Studies on mutations and their use in breeding.— The investigations on mutations are being continued according to plans outlined in previous reports. The timothy experiments furnish a large number of these types and much valuable material is being collected.

The field daisy is another plant that furnishes many different types of mutations. Several of these are being grown, and careful notes are taken as to frequency of occurrence and probable causes of such new types.

Studies on the cumulative action of selection.— These studies are being continued with wheat, oats, phlox, and beans. Many data are being collected which will add considerable evidence on the much-discussed question of the possible effect of cumulative selection.

Correlation of characters.— The studies on this subject which have been outlined in previous reports are being continued. Data are being collected on wheat, oats, corn, and other plants. In most cases careful attention is being given to the visible characters that may be correlated with yield, with the hope of being able to use such characters in further selections as indicators of high production. A number of papers have been published on this subject and others are in preparation.

A cooperative experiment in oats has been begun with the Montana Agricultural Experiment Station, with the purpose of studying the effect of change of environment on correlation. A similar cooperative experi-

ment with wheat has been begun with the Missouri Agricultural Experiment Station. It is hoped to continue these experiments for a number of years, and then bring together all the results in order to determine what changes have occurred.

Studies on bud variation.— These studies, which have been outlined in previous reports, are being continued and will be extended. Many valuable data on this subject are being collected, showing the possible worth of such variations in the practical breeding of crops such as the potato. Data are also being collected showing the possible occurrence of bud variation in timothy. These two lines of investigation are very important, since the general question of bud variation and its possible use in breeding is much discussed at present.

EXTENSION

During the past year the extension work of this Department has been conducted along the lines noted in the report for 1912 — first, cooperative and demonstrative work with individual farmers; second, distribution of new varieties of timothy, oats, wheat, corn, and the like; and third, educational activities, such as exhibits, lectures, instruction in extension schools and in the Winter Course, and special field meetings.

Cooperative and demonstration plats

The cooperative and demonstrative work has been increased considerably during the past year, especially in connection with wheat and oats. In connection with this work many new varieties are obtained. Some of these in the tests at Ithaca yield much better than do the commercial varieties. The methods and results of this part of the work are discussed under the heading of cereal-breeding. Although these new varieties may do well under the conditions at Ithaca, they may or may not be successful in other localities. The work of the past year has shown the importance and value of cooperative work in the testing of these new strains. The Department now has under way twenty-three cooperative experiments with oats and sixteen with wheat.

The cooperative work with timothy has also been increased. In the results for the four years with the broadcast tests of timothy, both at Ithaca and elsewhere, the superiority of certain strains has been demonstrated. Cooperative work is now under way for the purpose of increasing the seed of these superior strains and of testing further some of the newer ones. There are now fourteen cooperative timothy plats.

The timothy contest which was organized in Jefferson county last year is promising good results. Some thirty farmers are now growing individual plants of Cornell Standard; in one case nearly three thousand plants were

transplanted to the field. It is expected that there will be good competition at the contest next fall.

The number of cooperative plats of corn and potatoes has not been increased, there remaining the same number as last year — ten of the former and nine of the latter. The work with these plats is progressing satisfactorily and is giving good results with both crops; it has been impossible, however, with the present equipment, to increase the cooperative work with them. During the past year members of the Department made forty-six personal visits to cooperative plats.

Distribution of seed

The distribution of seed has increased considerably since the report for 1912 was made. This work has not been conducted long enough to show what the ultimate success will be. It is not the function of this Department to produce seed in commercial quantities; consequently, it must depend on the cooperation of individual farmers. The seed has been distributed in small quantities to a large number of individuals, rather than in large quantities to a few individuals. Not all of those who receive seed are successful with it, but a sufficient number will evidently carry the work on to completion so that the seed will soon be available in commercial quantities. During the past year the Department has distributed twenty-one samples of oats to growers in fourteen counties, ninety-seven samples of corn in forty-one counties, eight samples of wheat in five counties, and forty-five samples of timothy in twenty-two counties. In addition to this, a considerable quantity of seed was sent outside the State to agricultural colleges, experiment stations, farm bureaus, and the like.

Educational work

During the past year the Department has endeavored to render as much assistance as possible along educational lines. In this connection eighteen lectures and field meetings were conducted; also, fifteen days were devoted to instructional work in extension schools at Poland, Watertown, and Lincolndale.

Considerable material has been added to the plant-breeding exhibit. So far as possible, this has been arranged in permanent form. The exhibit was installed in the plant-breeding seed house at the College during Farmers' Week. It was shown at the State Fair and a part of it was sent to the county fair at Cazenovia. During Farmers' Week and at the State Fair, members of the Department were continually in attendance to demonstrate the exhibit. The experimental work of the College was represented by this exhibit at the Fifth National Corn Exposition, held in Columbia, South Carolina.

It is planned to add material to this exhibit year by year; and it is hoped that the exhibit, which is now kept in packing cases, may be housed in permanent quarters.

RECOMMENDATIONS

For the past three or four seasons the plants growing in the plant-breeding garden have suffered, and many results have been seriously affected, through the lack of proper facilities for obtaining water. Steps should be taken for furnishing an irrigating system of some kind for this garden.

The Department is very anxious to begin experiments in the breeding of leguminous crops, and it is hoped that funds for such work will be available in the near future.

H. H. LOVE,
Professor of Plant-breeding Investigations.

C. H. MYERS,
Assistant Professor of Plant-breeding.

DEPARTMENT OF PLANT PHYSIOLOGY

TEACHING

During the past year the staff of the Department consisted of two assistant professors and four assistants, all of whom were actively engaged in teaching. The courses offered and the enrollment are given in the following table:

Course	Subject	Term	Number of hours credit	Number of students registered	Total hours credit
7	General Plant Physiology	2	4	90	360
8	Advanced Plant Physiology	1 and 2	8	20	160
9	The Physiology of Fermentation	1	3	9	27
10	Physiology of Bacteria	2	3	11	33
12	Cytology	1 and 2	6	7	42
16	General Seminary	1 and 2	2	20	40
				157	662
Postgraduate					
	Major, Doctor of Philosophy			6	
	Minor, Doctor of Philosophy			20	
	Major, Master of Arts			1	
	Major, Master of Science in Agriculture			1	
				28	

The approximate number of credit hours of instruction devoted by these students to research would total 150. In addition to the above, three courses were given during the summer session with a total of 100 credit hours of instruction, making a grand total of 912 credit hours.

INVESTIGATION

The past year has been productive both with respect to the progress of investigations and with respect to the investigations published. The problems now under investigation or completed during the present year, and soon to be available for publication, are as follows; those starred are practically completed:

*M. J. Prucha. Physiological character and nature of the organism causing nodules on Canada field pea.

*M. J. Prucha. Vitality of the field-pea organism.

*M. J. Prucha. Factors influencing the virulence of the field-pea organism, that is, capacity of the organism to cause infection.

*M. J. Prucha and J. K. Wilson. Studies in cross-inoculation with legume bacteria.

J. K. Wilson. Physiological studies of the organism producing nodules on soy bean.

*J. K. Wilson. A method for seed sterilization.

*W. J. Robbins. Chemotaxy and phototaxy in fucus.

W. J. Robbins. Influence of certain inorganic reagents on enzyme production in molds and green plants.

*Christine F. Chapman and W. C. Etheridge. Influence of certain organic substances at various concentrations on secretion of diastase by certain fungi.

*L. Knudson and G. R. Hill, jr. The inception, season, and duration of cambial activity in peach, grape, and apple.

L. Knudson. Regulatory production of enzymes.

L. Knudson. The absorption and assimilation of organic compounds by green plants.

L. Knudson and W. J. Robbins. The rest period in plants.

L. Knudson and J. K. Wilson. Studies in legume inoculation.

H. M. Benedict. Senility in plants.

R. S. Nanz. Growth and metabolism in the apple tree.

*B. M. Duggar and M. J. Prucha. Sterilized soil as a medium for the distribution of the legume bacteria in pure cultures.

The following papers have been published during the year:

G. R. Hill, jr. Respiration of fruits and growing plant tissues in certain gases, with reference to ventilation and fruit storage. Cornell Univ. Agr. Exp. Sta. Bul. 330:373–408.

M. M. McCool. The action of certain nutrient and non-nutrient bases on plant growth. Cornell Univ. Agr. Exp. Sta. Memoir No. 2:113–216.

L. Knudson. Tannic acid fermentation I. Journ. biol. chem. **14**:159–184.

L. Knudson. Tannic acid fermentation II. Effect of nutrition on the production of the enzyme tannase. Journ. biol. chem. **14**:184–202.

L. Knudson. Observations on the inception, season, and duration of cambium development in the American larch [*Larix larcicinia* (Du Roi) Koch]. Torrey Botanical Club. Bul. **40**:271–293.

L. Knudson. Warming and imbedding stand. Bot. gaz. (In press.)

EXTENSION

The Department has been more active in extension work than ever before. A large number of letters of inquiry respecting many phases of

plant life have been received and answered. Especially numerous have been the letters concerning legume inoculation and the growing of mushrooms.

An exhibit was made at the State Fair, with an attendant in charge. During Farmers' Week an exhibit was shown in the laboratory, with a demonstration, and lectures were given.

The bulk of the extension work has been devoted to the distribution of pure cultures of legume bacteria, the Department having devised a very successful method of distributing the organisms in sterilized soil. The results obtained have been most gratifying, there being known not a single case in which inoculation was not secured. During the past season two thousand cultures were distributed to about seven hundred farmers throughout the State. A charge of twenty-five cents each was made for most of the cultures. In addition to the shipment of these cultures, two members of the staff spent a week in the field in cooperative work and in personal work with farmers. It is expected that a much larger distribution of cultures will be made next year.

For extension purposes the Department issued the following circular:

M. J. Prucha. Legume inoculation. Cornell Univ. Agr. Exp. Sta. Circ. No. 15:25-32.

RECOMMENDATIONS

As emphasized in its previous report, the Department is greatly in need of more greenhouse space. There should be one greenhouse reserved entirely for experimental purposes and a second for teaching work. It is hoped that a new house equivalent in size to the present one may soon be available for work in plant physiology.

In addition to more greenhouse space, increased laboratory space is necessary for proper accommodation of the students who desire work in plant physiology. During the second semester, especially, the instruction laboratory is congested. It has been the desire of the Department to keep the laboratory open to students at all hours of the day, so that they may drop in at any time and take observations and notes on their experiments or devote additional time to their work. The Department has maintained this liberal use of the laboratory and has found it very satisfactory in every way. The large number of graduate and undergraduate students now enrolled for work in the Department makes it almost impossible to permit of this freedom in the use of the laboratory. Furthermore, at present a single locker must be assigned to two students, whereas it is large enough for only one. The present floor space for instruction should be doubled.

LEWIS KNUDSON,
Assistant Professor of Plant Physiology.

DEPARTMENT OF PLANT PATHOLOGY

TEACHING

During the year 1912–1913 instruction has been offered in twelve courses, including two courses in the regular Summer School and one in the Winter Course. The teaching staff has consisted of eight members, an increase of two over the previous year. The total number of students registered for the various courses was 302, of whom 15 were in the Summer School courses and 62 in the Winter Course. This leaves 225 as the registration in the regular undergraduate and graduate courses. Last year 40 students were refused admission to the beginning course because of limited facilities; this year 35 students were turned away for the same reason, although it will be noticed that 101 more students were accommodated this year than last in the regular courses. This was made possible by the addition of two instructors and one small laboratory.

There are 21 graduate students registered for a major in the Department and 13 for a minor, for the degree of Doctor of Philosophy. There were registered 1 student with a major for the master's degree, and 2 with a minor. The increase in the number of graduate students, 7 over last year, is due in part to the establishment of industrial fellowships by groups of growers and in part to the increasing demand in institutions and experiment stations for highly specialized and well-trained technologists for pathological research.

INVESTIGATION

Satisfactory progress has been made during the year in the various lines of experimentation and investigation. As usual, many of the investigations have been accompanied by field experiments conducted from field laboratories, sixteen of which, located in fourteen different counties, have been maintained during the past summer. Much of the experimental work has been made possible through the financial cooperation of individuals, groups of growers, and other agricultural agencies. The various lines of work are mentioned in the order in which they have been inaugurated in the Department.

Grape-disease investigation.— As in all previous years since 1907, spraying experiments for the control of black rot of grapes was continued. The disease was no more serious this year than last, and the experiments for its control were without results.

The study of downy mildew of grapes, begun last year by C. T. Gregory, an instructor in the Department, has been continued and some very satis-

factory results have been obtained. Mr. Gregory has made important discoveries in regard to early spring infection by this fungus, and the results of his observations have been published (Phytopathology **2**:235-249. 1912).

Studies of the dead-arm disease of grapes have been continued. This work is now ready for publication except for recording data on a series of inoculation experiments.

Bean-disease investigation.— Work on the susceptibility of varieties of beans to various strains of the fungus causing anthracnose has been continued as time has permitted. The investigation is nearly completed and a technical bulletin setting forth the results will soon be published.

Spraying experiments for the control of anthracnose and other diseases of the bean were continued this year. Because of dry weather all summer, very little disease was present in most of the plats. The experiments indicate that thorough spraying with bordeaux will reduce the amount of, but will not entirely prevent, anthracnose where diseased seed is planted.

Seed selected from clean pods was sent to growers in various localities of the State, to be grown by them apart from their main fields. All reports from these growers have shown that plants from such seed have been entirely free from disease throughout the season. The dry weather of the season has minimized the value of such trials, since plants from seed not selected were in the main free from anthracnose.

Nursery-disease investigations.— The nursery-disease work has been continued much as in former years. Studies on the fire-blight disease in nursery stock have been completed and published as Bulletin 329 of the Cornell University Agricultural Experiment Station. The methods detailed in this bulletin have been employed successfully during the past season in two large nurseries. More attention has been devoted to investigations of some of the fungous diseases of nursery stock, particularly the shot-hole disease of plums and cherries and the leaf spot of quinces and pears. These investigations have been performed with the idea of determining more nearly exactly the optimum conditions for primary infection and of correlating infection periods with atmospheric influences, in order to develop a more rational basis for the satisfactory control of these troubles.

Ginseng diseases.— This work has gone forward in cooperation with the State Ginseng Growers' Association and with the Department of Cotton and Truck Disease and Sugar-plant Investigations of the Bureau of Plant Industry, United States Department of Agriculture. The various root rot diseases have received particular attention during the year, and J. Rosenbaum, the special assistant in charge of this work, has materially

advanced his investigations. Several articles dealing with various phases of the work have been published in the trade papers.

The use of sulfur as a fungicide.— The experiments on the use of sulfur in the control of potato scab, as outlined in the last annual report, have been continued. It is believed that the work of the present year will bring this phase of the investigation to an end. Should the results of the experiments now in progress confirm those obtained last year, the matter will be presented for publication as an experiment station bulletin.

The investigation of the fungous flora of the potato has developed to a much greater extent than was anticipated. It has therefore become necessary to confine this investigation almost exclusively to the species of *Fusarium* infesting potato tubers. A surprisingly large number have been isolated and studied in pure culture. Their capabilities of producing a rot of tubers in storage have been determined and their ability to attack living plants is now under investigation. With the conclusion of the pathological features of this investigation, the work will be ready for publication.

The work in control of hop mildew has been continued as formerly. Very satisfactory results have been obtained from dusting. The methods employed have been fully detailed in Bulletin 328 of this station, published in March.

The use of a dry fungicide for controlling various apple diseases has again received considerable attention. During the past season extensive experiments have been performed in order to determine the relative value of this method of applying the fungicide. It again appears that an insecticide applied in the dry state has been effective in controlling the more common chewing insects. Present indications are that a satisfactory control of apple scab has been secured. If actual counts and percentages soon to be taken bear out these observations, the data are of the greatest practical importance and should be prepared for immediate publication.

Experiments for the control of onion smut have been continued, including cooperative experiments with growers in the vicinity of Canastota. Thirty-five acres of onions have been under experimentation. Unfortunately, drought, wind, and frost have reduced this area to about ten acres. The sulfur-lime treatment as used last year has again given a marked increase in yield. Comparison of the sulfur-lime treatment with the formaldehyde treatment was nullified by high wind.

Attempts to control the late-blight disease of celery by means of a dry fungicide was delayed because of the late appearance of the disease, and was then cut short by early frost, so that no data have been obtained.

Forest-tree diseases.— The work on the chestnut-bark disease has been continued along much the same lines as formerly. A continued spread

of the disease leaves only a very small amount of our chestnut area unaffected. With the continued spread of the disease, the desirability of utilizing affected trees, and especially of reforesting with other more desirable species in the chestnut area, becomes increasingly apparent.

Apple-tree-canker investigations.— With the termination of the Byron fellowship, L. R. Hesler has devoted his attention entirely to a study of the apple-tree canker caused by *Sphaeropsis malorum*. Some important observations in connection with the fungus causing this disease have been made. Surgical methods and wound dressings have received further attention, and records have been taken of treatments previously made.

Fungicide investigations.— Extensive orchard experiments with a number of fungicides were inaugurated again this year. Unfortunately for the experiments, the amount of disease in the orchard selected for the work this year was not materially greater than in the one used last year, so that satisfactory progress has been prevented on this phase of the work. The laboratory features of the investigation are nearing completion.

Gladiolus-disease investigation.— This work has been performed by L. M. Massey, an assistant in the Department. The extensive experiments mentioned in the last report were without result, so that new lines of attack have been tried during the past year. Preliminary experiments seem to indicate that the organism causing the most serious disease may be killed at a temperature somewhat below the death point of the gladiolus corms. Extensive experiments with this fact in mind have been undertaken, as well as numerous other treatments of corms at digging time.

Fungicidal value of sulfate of iron.— Experiments on the control of raspberry anthracnose have been continued as for last year, but the results have not proved very satisfactory for sulfate of iron or for any other fungicide tried.

The use of sulfate of iron as a neutralizer of the caustic properties of lime-sulfur solution has been tried on an extensive scale in five different orchards. The points to be determined are: (1) whether the addition of sulfate of iron to lime-sulfur solution will prevent burning; (2) whether the combination is effective against apple scab and other fungous diseases of the apple; (3) whether the sticking qualities of the lime-sulfur are improved.

Violet-disease investigations.— The violet-disease investigations were practically terminated during the past year and the results of the work to date were published (Mass. Hort. Soc. Trans. **1913**: 85–102).

Crown-gall experiment.— This is a long-time experiment, with the purpose of determining the effect of crown gall on peach and apple trees under New York conditions. The trees have been looked over carefully

and as yet no difference can be detected between healthy and galled trees. It is not possible to distinguish the healthy trees without the aid of the planting guide.

Celery-storage investigations.— These investigations have been made in order to determine the effect of various celery diseases, particularly the late-blight disease caused by *Septoria petroselina*, on the keeping qualities of celery in storage. The results of experiments indicate that the late-blight disease is not a factor in the storage of celery. An entirely different affection has been found in stored celery and an organism has been isolated and studied. Numerous field tests planned for the present season were suddenly terminated by heavy frost.

Gooseberry-disease investigation.— An investigation of the nature, cause, and control of gooseberry necrosis has been instituted and satisfactory progress has been made.

Control of oat smut.— An investigation is being conducted in order to determine more efficient means of controlling this disease. The work is in charge of R. J. Haskell, an assistant in the Department.

EXTENSION

The extension work of the Department may be classified as follows: teaching at extension schools, demonstrations, exhibits, lectures, personal visits to farms, and correspondence.

Teaching at extension schools.— Lessons in plant diseases were given in extension schools at the following places: North Bangor (Franklin county), South Hampton (Suffolk county), Le Roy (Genesee county), Holley (Orleans county), and Johnstown (Fulton county). At these schools actual laboratory work was given, with microscopes and with specimens of diseased plants. The interest aroused by the lessons offers evidence of their value.

Demonstrations.— A number of visits were made to various sections of the State, on request, in order to demonstrate the method of treating oat seed with a solution of formaldehyde for the prevention of oat smut. The meetings were well attended and later reports from the sections visited proved that success attended the efforts of all who made the treatments.

A man was engaged by the Department and was stationed at Holley, Orleans county, to demonstrate to pear-growers the method of controlling fire blight. In all this representative made one hundred and fifty-three visits to farms surrounding Holley, demonstrating to growers the proper method of cutting out blighted limbs and of keeping the disease under control. In order to demonstrate that the disease can be controlled even when trees are badly infested, such an orchard, consisting of six hundred

and forty Bartlett trees, was selected and this representative was placed in charge. The diseased parts of trees were removed, and the orchard was kept free from disease during the remainder of the season by removing twigs as soon as they showed evidence of the blight.

As in previous years, the men associated with field laboratories have accomplished a large amount of extension work in connection with their investigations. In some cases the extension phase of the work is equal in importance to the investigative phase.

Exhibits.— Exhibits of the common diseases of orchard crops and of methods of control were made at the annual meeting of the Western New York Horticultural Society and of the New York State Fruit Growers' Association. Also, exhibits of the diseases of farm crops were made at the county fairs of Tioga, Oswego, and Wyoming counties and at the State Fair at Syracuse. An exhibit of fruit- and shade-tree diseases was made at the Rochester Industrial Exposition. Tree canker and wood decay, and the method of treatment, formed an important feature of the exhibit at the horticultural meeting at the State Fair and at the Rochester Exposition. An exhibit of the diseases of ginseng, and demonstrations of soil treatment for the control of root rots, was made at Syracuse at the annual meeting of the New York State Ginseng Growers' Association.

Lectures.— Forty lectures on some phase of plant-disease work have been given by members of the staff at farmers' institutes, at meetings of horticultural societies, and before granges, farmers' clubs, and other agricultural organizations. The number of such lectures given by members of the Department is increasing from year to year. The most satisfactory of such addresses are those given in the orchard or the field where the plants are growing, the talk being supplemented by showing the various diseases as they occur.

Personal visits to farms.— On request, members of the Department have made personal visits to farms in order to examine diseased plants and give suggestions as to their treatment. The traveling expenses of the representative of the Department have been paid by the person or persons making the request. Several tours of inspection have been made this year, in order that a better knowledge of disease conditions in various parts of the State may be obtained and control measures suggested when necessary. Eighty-four localities, representing thirty-two counties, have been visited by members of the Department during the year. Many of these localities were visited more than once, and some of them were visited several times.

Correspondence.— The correspondence of the Department is large. During the year 3815 letters were written, mostly in answer to inquiries regarding the control of plant diseases. In addition to these, several

thousand circular letters and cards were sent out giving notice to growers of the proper time and method of plant-disease control.

RECOMMENDATIONS

The most urgent need of the Department, as in the past, is for more satisfactory quarters. At the end of the year the entire Department was moved to the basement of the new Auditorium. The actual floor space is ample for the present needs of the Department, but the poor natural lighting reduces the available area at least one third. With the base of the small-paned windows five feet from the floor, the light will never be satisfactory for close microscopic work.

The intense congestion of former years has been relieved and it is now possible to accept all the regular students who seek instruction in the Department. The graduate laboratories, however, are still very much crowded. Increased floor space and better facilities for handling properly the increasing number of graduate students are among the imperative needs of the Department at the present time.

An elementary course in general plant pathology for special students is being urged more and more strongly by those special students who have had botany or biology in the high school and who have not time to carry the botany and biology regarded as essential prerequisites of our present collegiate course in the subject. This demand is a legitimate one; it can be met only by the appointment of an additional instructor in the teaching division and by providing additional floor space for the work.

There is increased need of cold-storage facilities for experimental work. A series of chambers that may be held at constant low temperatures would assist materially, and such facilities are absolutely necessary for the forwarding of a number of important lines of investigation.

The disease garden is now filled with trees and smaller plants of various kinds, and practically all of the present area is taken up with long-time experiments. The space between the rows of trees has been used for work with annuals, but the trees now make so much shade that the land can be used only for trees and for a limited number of shade-enduring plants. More land is needed for a disease garden, not only for experimental work by members of the staff but also as a place where suitable material can be developed for teaching purposes.

H. H. WHETZEL,
Professor of Plant Pathology.

DEPARTMENT OF SOIL TECHNOLOGY

TEACHING

The number of students registered in undergraduate courses for the year ending September 30, 1912, was 274. The number of undergraduates registered for the year ending September 30, 1913, was 445. This great increase was due largely to the fact that Course 1, Principles of Soil Management, was given three times during the year, and Course 7, Manures and Fertilizers, was given twice — each of these courses having been given during the Summer School. This repetition of courses not only results in increasing the capacity of the laboratory, but also makes it less difficult for students to schedule the work.

Fourteen graduate students were registered for major and minor subjects in the Department.

The course in drainage and irrigation is now given in cooperation with the Department of Rural Engineering. It is expected that this change will greatly increase the efficiency of the work in this subject.

INVESTIGATION

Adams fund investigations

One of the investigations conducted under the Adams fund has been completed; three are still in progress. The investigation completed is the one previously reported as *an examination of certain properties of an unproductive soil.*

This investigation was occasioned by the occurrence of a number of small areas of land, on the experiment field, on which plant growth was poor. These areas were so unproductive, with so little apparent cause for their infertility, that an investigation of the matter was begun under the direction of Professor Thomas F. Hunt, who was at that time Agronomist of the Cornell University Agricultural Experiment Station.

One of the early observations made in the experiment was that. when soil from the unproductive area was removed from the field and placed in pots, the first crop grown on it was better than that produced by soil from surrounding land which in the field was much more productive. This characteristic has remained constant up to the present time. When moved to the greenhouse in a solid block, thus permitting of very little aëration, the soils possessed the same relative productiveness that they did in the field.

The part of the field on which these unproductive spots occurred was

divided into one hundred and ten plats 5½ feet by 8 or 12 feet in size, and these plats were cropped with millet for four consecutive years in order to ascertain whether the relative productiveness of the plats was constant or was merely a chance occurrence. The relative productiveness was found to be a fairly constant characteristic especially for certain plats, and thirty-eight of these, characterized by very high and very low yields, were selected for study.

The soils of these plats were subjected to examinations of their texture, their chemical composition, their content of organic matter, their degree of compactness, and their moisture and nitrate contents at different times. Studies were made also of the effect of aëration on the growth of plants in the soils and on the water-soluble matter. Plants were grown in water extracts treated with carbon-black and untreated. Two plats, representing high and low productiveness, were selected for an examination of their bacterial flora at monthly intervals through a period of two years.

The data, when correlated, brought out the fact that the lower-yielding plats were more compact than the higher-yielding ones. The degree of compactness was due in large measure to the quantity of organic matter, and in less degree to the soil texture. There was a close correlation between the rate of nitrate formation and the productiveness of the soils, which indicates that the less productive soils were too compact to permit of the processes necessary to a high state of fertility. This is substantiated by the examination of the effect of aëration, which was to temporarily increase the productiveness of the poorer soil beyond that of the better and to greatly increase the formation of nitrates.

The other three investigations under the Adams fund are being continued. A brief statement of the nature of each follows:

1. *Influence of soil moisture and temperature on the availability and utilization of plant nutrients in soils.*— This study is undertaken for the purpose of ascertaining what effect, if any, a given moisture content in the soil may exert on the condition in which the plant nutrients are held in that soil. The quantity of moisture that a soil contains has been generally conceded to be the most potent factor in determining crop yield. It is not known, however, to what extent the influence that it exerts is directly on the crop, and to what extent it operates by making more or less soluble the plant nutrients in the soil. These questions involve the activity of the soil bacteria, modifications in the colloidal condition of the soil, the hydrolytic action of water, the equilibrium of the solutes in the soil water, and the like.

2. *A study of the composition and concentration of water-soluble material of soils under different methods of soil treatment.*— The main problem has

been an investigation of the formation of nitrates and other water-soluble matter in soils as affected by the growth of certain higher plants. The influence of some other conditions have of necessity been studied, in order to eliminate them from the experimental results. The experiments deal with the influence of the plant on the soil in distinction from the effect of the soil on the plant. It is a phase of soil investigation fundamental to a study of crop rotations.

3. *Investigation of the conditions under which lime is removed from soils, and of the changes that accompany its removal.*— The tendency of soils in a humid region to lose their basic constituents may be more or less controllable. The effect of different crops, cultivation, fertilizers, and the like on the quantities of calcium and other constituents of the drainage water is being studied by means of large tanks filled with soil from which the natural drainage is collected.

Other investigations

Examination of the chemical composition and certain physical properties of the more important types of soil in the State.— Representative samples of certain types of soil are taken from three different areas of the same type, located in different parts of the State. Chemical analyses of the completely dissolved soil are being made with these samples, in order to ascertain whether the composition of a soil type, as now classified, is fairly uniform and is sufficient to distinguish any type from other types.

A comparison of the practice of fertilizing for the hay crops with that of fertilizing for the grain crops in a rotation of timothy and clover three years followed by maize, oats, and wheat each one year.— The common practice is to fertilize the grain crops rather than the hay. It is a question whether the application of fertilizers to the hay crops would not be more profitable, since by increasing the yield of hay the quantity of sod is increased and this is in itself a fertilizer. Also, the hay crop is the most valuable crop if large yields are obtained.

The influence of the application of calcium in certain different chemical combinations, and of ground limestone in different degrees of pulverization, on the productiveness of certain loam and clay soils.— It is a question in fertilizer practice, at the present time, whether at certain prices burned lime or ground limestone is the more profitable, and also what degrees of fineness in the ground limestone should be used. The experiments involve the use of these forms of calcium in different quantities on different soils of loam and clay texture.

Top-dressing alfalfa with farm manure and with different fertilizers, also with lime, when it has been seeded for a number of years and the yields have

begun to decrease.— Alfalfa is a crop that will remain on the land for many years under favorable conditions. Its high value is now thoroughly appreciated in this State. Methods for increasing its productiveness and maintaining its vitality after it has been growing for a number of years and has begun to deteriorate should be found. The experiment is planned in order to ascertain whether this can be done or whether the alfalfa must be resown periodically.

Continuous cropping of land with maize and hay.— Numerous experiments have demonstrated that continuous cropping of soil without manures decreases the crop yields, but in such experiments the supply of organic matter has not been maintained. In this experiment it is being attempted to keep up the supply of organic matter by growing a hay crop four years and a maize crop one year in every five. The hay will be removed regularly but the sod will be plowed under.

The nitrogen balance in soils growing different legumes, and in soils growing timothy, when the hay crops are removed.— Experiments conducted by the Department have shown that, as compared with grasses, legumes increase the rate of nitrate production in soils. It is well known that legumes use nitrate nitrogen in large quantities. It is therefore a question how much of the large quantities of atmospheric nitrogen fixed by legumes is left in the soil when the crops are removed, how the different species of legumes differ in this respect, and how they compare with timothy.

The use of fertilizers on a nurse crop with which timothy or timothy and clover are sown.— A luxuriant growth of a nurse crop with which grass is seeded has been observed to delay the growth of the grass. The manuring of the nurse crop results in its better growth. It is a question whether the profit from the increased value of the nurse crop will offset the delayed growth of the hay crop. The experiment is also designed to test the profitableness of added fertilizers in separate portions, the nitrate nitrogen being reserved for use directly after removing the nurse crop.

The fertilizer needs and lime requirements of certain muck soils.— Muck soils are of great value when properly handled. They vary widely in their composition and properties. The fertilizer and lime requirements of such soils differ with different deposits. Local tests are being made and it is expected that information of general application will be gained.

Local fertilizer tests.— Tests of different kinds and quantities of fertilizers applied to a rotation of crops, with and without the application of lime, are being conducted for the purpose of ascertaining the fertilizer needs of the particular soil under experiment. When a sufficient number of these are in operation, they will furnish information as to the possibility of determining the fertilizer needs of any soil type by conducting experiments on a representative soil of that type.

EXTENSION

The activities of this section may be divided into two groups: the first aims to collect data concerning the nature, distribution, and management of the soils of the State; the second is educational, and aims to bring before the people of the State who are not registered in regular university courses the fundamental facts concerning soil improvement and the results of demonstrations, both at Cornell University and elsewhere, in so far as they apply to soil conditions in the State. In the first group is included (1) soil surveys, (2) drainage surveys, (3) irrigation studies, (4) composition of soil types, (5) field-plot experiments, and (6) miscellaneous investigations and observations. In the second group are included (1) preparation of bulletins, (2) extension schools, (3) farm-train lectures and exhibits, (4) exhibits at local fairs and at the State Fair, (5) miscellaneous lectures, (6) visits to farms, and (7) correspondence.

Field studies

Soil surveys, in cooperation with the United States Bureau of Soils, have been in progress in three areas:

1. The field work in Orange county was completed in November. Of the total of 849 square miles of that area, 199 square miles were traversed after October 1. The variety of soils in Orange county is above the average. The central part of the county is occupied by soils derived from a shale and sandstone glacial till, deficient in lime and classed with the Dutchess series. Associated with these are small areas of soil derived from calcareous glacial till. The southeastern part of the county is occupied by a mountainous region, where the soils are generally thin and stony and are derived by glacial action from the granitic and trap rocks of that region. The western part of the county reaches into the stony glacial soils of the Catskill Mountains section and the soils are of very low agricultural value. Several miscellaneous types of soil of small extent, together with a small amount of alluvial soil, were also encountered. The most important special feature of the soils of the county is the large areas of muck soil in the lower Wallkill valley, a considerable part of which is utilized for the production of onions, celery, lettuce, and related crops.

2. The field work in Oneida county was continued during the fall of 1912 and renewed in June, 1913. By September 30 approximately 1000 square miles of the total of 1180 square miles in the county had been traversed. It is expected that the field work in Oneida county will be completed during this field season. The variety of soils in Oneida county is greater than in any other area thus far surveyed in the State, if not

in the United States. The county occupies a peculiar position at the meeting-point of several groups of soil conditions, namely: the glaciated shaly hill lands of the south; the glacial lake plains of the middle; the calcareous glacial till of the central and southern sections; the granitic till of the northern part; and the morainic, swamp, and alluvial soils associated with the other groups. Over sixty types of soil have been recognized by the field party thus far. It is particularly important that a correct classification of these soils be made, because of the relation that they have to the correlation of types over wide areas of the State; and special attention is being given to the matter by this Department and by the inspectors for the United States Bureau of Soils.

3. A survey was begun in Chautauqua county in June, and on September 30 approximately 500 square miles of the 1062 square miles in the county had been traversed. This survey will include the revision of the Westfield sheet, which lies entirely within Chautauqua county on the shore of Lake Erie and takes in the greater part of the Lake Erie grape belt. The Westfield survey was made by the United States Bureau of Soils. It was the first soil survey made in this State and was completed in 1901, when soil survey work was very new; consequently some changes in separations and names of types will be necessary in the revision, in order to make the work coincide with that now being done.

The soil conditions in Chautauqua county are relatively simple. They consist of the glaciated shale and sandstone uplands of the southern two thirds of the county, embraced in the Volusia series; the glacial lake deposits on the Lake Erie plain, recognized chiefly as the Dunkirk series; the glacial stream outwash terraces in all the larger valleys, classed as Chenango; and the alluvial and swamp soils, which are of limited extent.

The most important special interest of the region is grape-growing on the Lake Erie plain and foreland. This is probably due to climatic as well as soil conditions.

The Conewango valley, in the southeastern part of the county, presents some rather large drainage problems, together with problems concerning the utilization of muck and other wet soils. The higher hills — covered by Volusia soil — in common with a large part of southern New York, also present important and complicated problems concerning the maintenance of soil fertility and the utilization of these lands.

The total area of soils surveyed in the State to this date is 12,145 square miles, distributed in twenty-one areas.

Drainage surveys.— Seven farms have been visited, with the purpose of giving assistance in the planning of farm-drainage systems. These surveys and plans have been in the nature of a reconnoissance, owing to the lack of facilities for giving more extensive aid. A number of calls for

assistance could not be met. Data are continually being accumulated concerning the conditions, methods, and results of drainage in the State, and these data emphasize the large importance of this subject in increasing the productive capacity of our soils.

Irrigation studies.— There is an increasing interest in the practice of irrigation in New York. Many persons inquire concerning its practicability and the best methods to be pursued. A number of irrigation plants are in operation in the State in connection with the production of truck and small-fruit crops. There is need of a systematic investigation of this subject.

In connection with the Rochester Railway and Light Company and the proprietors of the Baker farm, north of Rochester, an investigation of irrigation methods was begun in the spring. The lighting company is interested in the development of farm uses for electrical power, and the company therefore wishes to determine to what extent and under what conditions it is practicable for the farmer to use a moderately expensive form of power for pumping to supply and distribute water. The employee of the company with whom our cooperation is effected is a graduate of this College. He gives personal attention to the maintenance and conduct of the investigation in the field. The Baker farm is devoted to the production of fruit and some vegetables. The soil is a light sandy loam. The farm has a water supply suitable for experimental purposes. The crops under study are peaches, cherries, blackberries, raspberries, and beans. Benefit to the crops is noted, but no conclusions have been drawn from the season's results. The work is to be continued.

Composition of soil types.— Work on the analyses of representative samples of type soils in Tompkins county has been continued.

Field-plot experiments.— The first regular crop on the field plots located at Virgil was grown this season. The crop consisted of potatoes. This is the beginning of a series of tests embodying one hundred and forty-four plots, to be continued for a period of years in order to determine the best means of improving the Volusia silt loam in that region. Thus far the Department has worked in cooperation with a representative of the agricultural division of the State Normal School at Cortland.

Another experiment, involving the same series of treatments of plots, has been located on the farm of the School of Agriculture at Alfred, in Allegany county. This also is on Volusia silt loam. The school will perform the labor necessary in order to maintain the plots. A severe hailstorm in July seriously injured the crop of potatoes on this area.

Miscellaneous investigations and observations.— Various data concerning soil conditions are collected from time to time as supplementary to other lines of work. One of these minor features is the observation of the effects

of the use of dynamite on certain soil conditions. It seems safe to say that the use of dynamite to break up hard subsoil and afford drainage has a very limited practical use in New York. On any of the types of soil having a deep, compact subsoil, the use of dynamite must be coupled with that of some form of tile or other material for the transmission of water. The trials on and near the university farm have thus far had no observable effect.

Educational work

Preparation of bulletins.—(See Publications.)

Extension schools.— This Department took part in eight extension schools, and devoted twenty-eight days to actual instruction, in the months from December to March inclusive. The courses given dealt with fundamental principles of soil improvement, with special reference to the interests of the region in which each school was held.

Farm-train lectures and exhibits.— Lectures and demonstrations were given in the educational farm train run for three days over the Harlem Division of the New York Central Railroad, November 12 to 14 inclusive. Nine lectures were given.

Exhibits at local fairs and at the State Fair.— Representatives of the Department attended the State Fair and five local fairs with an educational exhibit, during the latter part of August and September.

Miscellaneous lectures.— Aside from the addresses made in organized courses as noted above, thirty-seven lectures were given before a variety of audiences, including farmers' institutes, church conferences, Farmers' Week, granges, and other organized bodies.

Visits to farms.— The Department is frequently called upon to inspect farms with the view of giving advice concerning the character and possibilities of the soil and methods for improvement. It is not attempted to meet all these calls; but in so far as such work promises real aid and can be combined with the other activities of the section, the calls are accepted especially when for the purpose of public institutions. In this manner fifteen farms were examined during the year, of which seven were for public institutions.

Correspondence.— During the year 3000 letters were written in the general correspondence of the Department, in addition to which 1856 circular letters were sent out.

PUBLICATIONS

T. Lyttleton Lyon and James A. Bizzell. The influence of a preceding crop on nitrification in soil. Journ. indus. and eng. chem. 5:136–138.

T. Lyttleton Lyon and James A. Bizzell. The influence of alfalfa and of timothy on the production of nitrates in soils. Centbl. bakt. 2:37:161–167.

T. Lyttleton Lyon and James A. Bizzell. Water-soluble matter in soils sterilized and reinoculated. Cornell Univ. Agr. Exp. Sta. Bul. 326:205–224.

T. Lyttleton Lyon and James A. Bizzell. The plant as an indicator of the relative density of soil solutions. Am. Soc. Agron. Proc. **4**:35–49.

T. Lyttleton Lyon and James A. Bizzell. Is there a mutual stimulation of plants through root influence? Am. Soc. Agron. Proc. **5**:38–44.

T. Lyttleton Lyon and James A. Bizzell. Formation of nitrates in soil after freezing and thawing. Am. Soc. Agron. Proc. **5**:45–46.

Elmer O. Fippin. Onions on muck soil. Report of New York State Vegetable Growers Assoc. **1912–1913**:64–68. (The same article appeared in The Vegetable Grower, April, 1912, and was listed in the last annual report of the College.)

Elmer O. Fippin. Needed changes in the drainage laws of New York State. Proceedings of the 73d Annual Meeting of the New York State Agricultural Society. New York State Agr. Dept. Bul. 47:1178–1187. (Also, Tribune farmer **12**:586:3.)

Elmer O. Fippin. The importance and value of reasonable drainage of the soil. (Tribune farmer **12**:599:1–2.)

Elmer O. Fippin. Tilth and tillage of the soil. Cornell reading-course lessons for the farm **2**:42:157–184.

RECOMMENDATIONS

Soil-improvement plats.— A series of soil-improvement plats should be established on different soil types, to be continued for a number of years. These would serve three purposes: (1) to determine the needs of each soil type; (2) to serve as a demonstration in each community; (3) to supply a source of experiment data and a basis for research.

Glasshouses.— It is desirable that the glasshouses used by the Department should be of a kind especially adapted to the needs of the work, instead of being of the type used for horticultural work. It would also be an economy in time and in energy to have the two houses side by side, instead of separated as at present.

T. LYTTLETON LYON,
Professor of Soil Technology.

DEPARTMENT OF HORTICULTURE

TEACHING

During the past year the teaching work in horticulture progressed very satisfactorily. At the beginning of the year the courses in Nuciculture and Subtropical Pomology were transferred to the Department of Pomology, and the course in Evolution of Plants was dropped because the work was practically covered by courses in the Department of Plant-breeding. This permitted concentration on the two main lines of horticultural work remaining in the Department. There was an increased registration in all the floricultural and vegetable-gardening courses. The total number of students receiving instruction in flower- and vegetable-growing was 374. The number registered for this work in the Winter Course was 69.

The new courses in Garden Flowers and Home Vegetable-gardening were exceedingly popular among the students. Courses giving the broad elementary principles of these subjects, if taught in their relation to the farm, will continue to attract students in increasing numbers.

In those courses requiring greenhouse facilities the Department was hampered by lack of sufficient space. Although having but 6720 square feet of greenhouse space, the Department was called upon to provide instruction for three hundred and eleven students. The successful accomplishment of this task was an undue strain on the time and strength of the head of the Department, leaving too little time and energy for other important matters. It is hoped that the additional glass area provided for in the appropriation passed last spring will relieve this condition and allow the giving of three additional courses, which will be offered as follows:

Commercial Floriculture.— Lectures, assigned readings, and discussions on greenhouse plants and on the packing, handling, and marketing of cut flowers and plants for retail and wholesale markets. The work in the principles of greenhouse management heretofore given in the first semester of the course in commercial floriculture will hereafter be known as Greenhouse Management. This course is made a prerequisite for the courses offered in commercial floriculture, except for those who have had some practical experience. As the courses are now arranged, commercial floriculture is begun in the second semester and continued during the first semester of the following year. Thus a student is enabled to follow the development of the cut-flower crops from the cuttings to maturity.

Amateur Floriculture.— The propagation and culture of plants suitable for window garden and dooryard, including a study of containers, soils, fertilizers, insecticides; also, preparation and planting of flower beds.

Propagation and Culture of Ornamental Shrubs.— A course designed to acquaint the student with methods of propagation, pruning, and culture of shrubs.

Graduate work

Ten graduate students registered for work in the Department. All but one of these were candidates for advanced degrees; three were candidates for the doctor's degree. Four of the candidates completed their work.

Winter Courses

As in previous years, instruction was given along three lines — fruit-growing, vegetable-growing, and flower-growing. There was an increased registration last year; however, with the exception of the instruction in fruit-growing, all the work was given by the regular staff. In addition to the specialized groups of courses, a special course in general horticulture was given for the benefit of students in general agriculture.

INVESTIGATION

Peony studies.— The collection of peonies was successfully removed to the new floricultural area. It is expected that new varieties will be added as they appear. Many of the species are being added this fall, so that the collection will remain a living herbarium.

Sweet-pea studies.— This work is practically completed. During the past year two hundred varieties of sweet peas were grown, and descriptions of the new varieties were made. The novelties will be grown next year, but the number of varieties to be tested each year will be much less. A bulletin is now completed giving complete descriptions of the varieties of the outdoor type.

Gladiolus studies.— Much of the energy of the Department this year was directed toward the work with gladioli. More than five hundred lots of corms, comprising four hundred and ninety varieties, were tested and careful notes were made. A large number of photographs were taken.

Rose studies.— A test of varieties of climbing roses was begun last spring. A complete collection of all the varieties of this class offered by American nurserymen has been planted, and notwithstanding the dry season the plants have made a fine growth. It is now proposed to undertake a test of bush and dwarf varieties. This work is needed, for there is no flower that is more popular. Unfortunately, however, much diffi-

culty is experienced in growing roses. The new hybrids promise better results, and the Department should assist in the development and popularization of the new types.

Aster studies.— A study of the various types and varieties of asters was undertaken by a graduate student of the Department. It is planned to continue the work for at least another season.

Other studies of flowers.— As rapidly as possible, work will be undertaken with other important flower crops. Each year there is an increase in the number of inquiries received concerning this subject, and one of the greatest needs at present is the preparation of horticultural monographs on all the important flowers.

A large collection of annual flowers was grown this year on an experimental area set aside for this work.

Vegetable experiments on muck lands.— This work was continued along the same lines as heretofore. The experimental areas are located at South Lima, Clyde, and Canastota, where a considerable vegetable-growing business has developed. It is hoped that with the data for another season the results will be sufficiently conclusive to warrant publication.

Vegetable-accounting.— The collection of data in this manner was continued during the year. The statistics on various crops, compiled from the data gathered from growers, will be very valuable. It is recommended that sufficient provision be made for the extension of this work.

Lima-bean studies.— A study of the growing of lima beans is in progress. Last season the work was done on Long Island; this year cultural tests were made at Ithaca. The study includes the types, varieties, fertilizers, distance apart for planting, culture, and the like, of this bean.

EXTENSION

The Department was fortunate in engaging a capable man for extension work and therefore was able to do much more along this line than it has previously accomplished. The amount of extension work done, however, was limited because the extension instructor had to give three hours of instruction throughout the year and seven additional hours during the Winter Course. The following account will indicate the scope of the extension activities of the Department:

Vegetable-gardening and demonstration train.— A vegetable-gardening train was run over the West Shore Division of the New York Central Railroad from Newburg to Troy, during the week of March 31 to April 5. This train consisted of two cars, one for the exhibit and one for lectures and demonstrations. It was in charge of F. S. Welch, an agricultural representative of the railroad company. Stops were made at Newburg, Kingston, Catskill, Coxsackie, Albany, Schenectady, and Troy; with the

exception of those at Catskill and Coxsackie, the stops were for one day each. The exhibit consisted of fresh and preserved vegetables, greenhouse models and material, hotbed models, potted plants, photographs, charts, tools, cultivators, drills, seeds, publications, and the like. Lectures were given on greenhouse construction, planting home grounds, and school gardens, by Professor Beal; on planting and transplanting vegetables, planning vegetable gardens, and home vegetable gardens, by Mr. Wilkinson; on intensive vegetable-growing, market gardening, and growers' organizations, by Mr. Work.

This was unquestionably the first train ever run in America in the interests of vegetable-growing. It was very successful and, although the train was run immediately following the disastrous floods, the attendance was good. Fourteen hundred persons visited the train and the men in charge were kept busy answering questions. From the great interest manifested, it was the opinion of all those connected with the enterprise that much was accomplished in showing the people what the College is trying to do in solving some of the vegetable-growing problems.

Brief survey trips.— Short trips were made for the purpose of ascertaining the vegetable-growing conditions on Long Island and in the Irondequoit section. All the developed muck areas in central New York were visited. In addition, visits were made to new muck areas at Oneida Lake and Rome, on the request of growers seeking advice. At the request of the county bureau agent, a trip was made through Chautauqua county.

Assistance in marketing.— One of the results of the Long Island trip was a study of the marketing problem. The market conditions were ascertained, and efforts were made to assist the growers in finding markets and especially to place grower and consumer in direct connection with each other.

Extension schools.— Assistance was given in only two extension schools, but this was largely due to the fact that schools were not arranged for in localities where the vegetable-growing industry is largest.

Granges and other organizations.— Addresses were made to the granges at Brockton, Palatine, Ovid, Newfield, Springport, and Ira. A series of eight lectures on home gardening was delivered under the auspices of the Buffalo Young Men's Christian Association. During the period from March 11 to April 30, addresses were given before the Western New York Horticultural Society, the Syracuse Vegetable Growers, and the State Vegetable Growers' Association. Lectures have been delivered at Mineola, Jamaica (three), Richfield Springs (three), Warren (two), Olean (two), Portville, Sheridan, and Frewsburg.

Exhibitions.— The vegetable exhibit at the Land Show in New York was set up by the extension instructor of the Department. The Depart-

ment made exhibits at the State Fair and at Poughkeepsie. In addition, judging was done at Bath, New York.

Home gardening.— The program for one day during Farmers' Week was devoted to home gardening, and the attendance was greater than that at any other of the horticultural sessions. Along this line, five visits were made to Owego in the interest of vacant-lot gardening in cities. Assistance was given in planning gardens and also advice as to care of gardens. This work should be stimulated in every way possible, for the high cost of living can be reduced to a large extent by the growing of a vegetable garden. A large proportion of the population in the smaller cities have room for a garden, and, even where this is not the case, vacant lots can frequently be utilized.

State institutions.— Visits have been made, at the instance of the State Department of Agriculture, to the Hudson River State Hospital and to the Letchworth Village at Thiells, New York.

Experiments on muck lands.— These experiments, being cooperative, were placed in charge of the extension division this year. Several trips have been made for conducting and inspecting the work.

Publications.— Two Reading-Course Lessons for the Farm were prepared, entitled respectively "Hotbed Construction and Management" and "Home-garden Planning." There were also published two lessons in the Reading-Course for the Farm Home, "Vegetable-gardening" and "The Flower Garden."

Correspondence.— The mailing lists for the Department were revised and a large number of names were added. More than three thousand circular letters and return postals were sent out for the purpose of collecting data on vegetable crops. A card index has been made of celery-growers, potato-growers, lettuce-growers, and growers of other crops. A classified list by counties is being made. This will enable the Department to get in touch with the growers of any particular crop or to circularize the growers in any county. All departmental activities in the extension field have entailed a correspondence of about thirty-five hundred letters, in addition to those referred to above.

RECOMMENDATIONS

The need of increased greenhouse space is again emphasized. The Department is unable to give any kind of practical instruction in the growing of roses or of violets, both of which are leading floricultural industries. The same is true of cucumber- and tomato-forcing. Even with those crops that are grown by the Department no adequate training can be given in packing or marketing methods. It is probable that the

increase in students will be such that the Department will not be able to provide all the training that individuals require; but to be absolutely unable to provide any laboratory work in some of the most important phases of floriculture and vegetable-gardening, is extremely trying to those concerned in building up the instruction in such special lines and disappointing to those who desire such training.

The writer desires to call attention to all the recommendations made in the last departmental report concerning the need of facilities for investigative work.

It is recommended that a photographic laboratory and field office, as well as a tool house, be provided at the Craig Field (formerly the Bool farm). At present a part of the barn is used for the storage of tools; in remodeling the buildings it is recommended that a separate tool house and barn for the Department of Floriculture be constructed on that part of the farm assigned to the Department. Similar quarters should be provided for the work in vegetables.

It is recommended that funds be provided for surveys. There are seventeen thousand commercial vegetable-growers, and thus far the Department has been able to reach only a little over three thousand of them. They can be reached through surveys in the leading vegetable-growing sections. Accurate knowledge of the conditions throughout the State is greatly needed, for the reason that this industry has not received much attention during the twenty-five years in which the agricultural experiment stations have been in existence and accumulated knowledge in regard to vegetable-growing is not available.

A greenhouse survey should be made in order to obtain definite information in regard to greenhouse-building and -heating as well as information on the crops grown. Such a survey would reveal the problems that confront the growers of various crops. It would be of great value in assisting those in charge of the floricultural and vegetable-gardening work to determine the greatest and most important problems. This has been urged before and will probably now be undertaken.

It is recommended that, in view of the fact that no department covers the horticultural field, assistance to the home gardener be kept constantly in mind. As soon as the time of the extension officers in any division shall be taken for work of a commercial character, a second man should be appointed to work with those who desire assistance in home gardening. The latter is the most extensive field in which to work, and, from the standpoint of the State in seeking to aid its citizens, it is the work most worth while. A great saving would result if there were two million home vegetable gardens in New York State every year, as there should be. In order to make good home gardens of flowers and vegetables a reality,

reading-course lessons should be issued, garden clubs formed, personal aid given to civic improvement organizations, women's clubs, and school officers, and correspondence encouraged.

VALEDICTORY

The development of horticulture in North America, and particularly in New York State, has been so rapid and has become so specialized on the commercial side that it has been considered wise to separate the work. Accordingly, in 1910 a Department of Pomology was created at the College. The wisdom of this course has been justified by the results. The death of Professor Craig, occurring late in the summer of 1912 after plans for the year's work had been made, caused the continuance of the Department of Horticulture along former lines. As during the illness of Professor Craig, the writer continued to act as the administrative head for the year. The disintegration having commenced, there was no sufficient reason why the remaining lines should not be separated. Since the need of specialized instruction and the investigation of a multiplicity of problems justifies a considerable staff giving their whole time and attention to their respective lines, a Department of Floriculture and a Department of Vegetable-gardening have been formed out of the Department of Horticulture, and the latter has been discontinued.

When the horticultural history of the time is written it will record the achievements of the two distinguished teachers, the only two professors of horticulture to occupy that chair in Cornell University — L. H. Bailey and John Craig. This report, therefore, concludes the accomplishments and records the passing of an old and honorable department in the New York State College of Agriculture at Cornell University.

A. C. BEAL,
Assistant Professor of Floriculture.

DEPARTMENT OF POMOLOGY

TEACHING

The instruction in pomology is planned to meet the different needs of the students, and to that end the courses provide training for practical work, for teaching, and for research. A course in elementary pomology consisting of two lectures and one recitation, given in the first term, covers the fundamental principles. Following the elementary course the practical training, consisting of two lectures and one recitation, is given in the second term. Practice work is provided in a laboratory course, which in 1912–1913 was given in the fall term but which will be offered hereafter in the spring term.

Additional work in pomology is taken up by other courses. A course in advanced practical pomology provides training in the varieties of different fruits, in judging work, and in the preparation of plans for planting and managing orchards. Courses in small fruits, spraying of fruit trees, and systematic pomology, each taking up its particular field, prepare the student for practical and experimental work.

Hitherto no distinction has been made between regular and special students. The members of the Department have felt, however, that better work could be done if these classes were separated. The courses for 1913–1914 provide for this separation.

The Department offered regular courses in the Summer School for the first time this year. The results were most gratifying, the registration in each course being large as is shown below.

The number of students registered in pomological courses during the year 1912–1913 is as follows:

Course	Subject	Number of students registered	
		First term	Second term
1	Elementary Pomology	195	......
1a	Elementary Pomology (laboratory)	120	......
2	Practical Pomology	......	122
4	Bush Fruits	......	70
6	Spraying of Fruit Trees	......	26
6a	Spraying of Fruit Trees (no credit)	......	20
8	Advanced Practical Pomology	99	......
10	Systematic Pomology	......	18
14	Seminary	......	14

Course	Subject	Number of students registered: First term	Number of students registered: Second term
33 (Hort.)	Nuciculture	.....	14
	Graduates taking major	6	1
	Graduates taking minor	4	2
		424	287
60	Commercial Fruit-growing (Winter Course)	53	
A	General Fruit-growing (Summer School)	37	
B	Small Fruits (Summer School)	26	
C	Advanced Pomology (Summer School)	7	
		123	
	Total registration in 1912–1913, 834.		

INVESTIGATION

Research work in pomology was begun in earnest during the year. Professor W. H. Chandler came to the Department in August to take charge of the research work, to which he will devote his entire time.

Considerable attention has been given to the care and planting of new orchards. About fifty acres of land on the university farm has been set aside for pomological work. The planting is now nearly completed. In connection with the planting of these orchards, the first two experiments mentioned below were continued during the summer. These are long-time experiments, extending over several years.

Variety tests.— A collection of varieties of each fruit is being made. The purpose of this collection is twofold: first, to study commercial varieties as regards hardiness, productivity, variability, and quality; second, to study new varieties as regards adaptability to conditions in New York.

The value of selected scions.— In the case of several varieties of apples, scions have been selected from bearing trees which are known to be productive and the fruit of which is excellent as to type. Scions are chosen also from the nursery row and from trees the fruit of which is inferior in type. The products will be compared.

Irrigation in New York as it affects the peach.— In cooperation with the Department of Soil Technology at the College and with W. E. Bargar, of Lockport, an experiment was started in the spring of 1912 to determine the results of irrigating a peach orchard. Mr. Bargar furnished the peach

orchard and the money for the irrigating plant, which when installed had a capacity of four hundred gallons per minute. Water has been applied at regular intervals during the summers of 1912 and 1913 and the results are computed for the summer of 1912. Although the orchard bore no fruit in 1913 the work of irrigation proceeded. The experiment will be continued for three years.

Irrigation in New York as it affects the apple.— An experiment was begun in a bearing apple orchard near Charlotte, in cooperation with the Rochester Railway and Light Company. Plats in this orchard were irrigated at intervals during the season of 1913. The experiment is to be continued until conclusive results are obtained.

EXTENSION

During the college year members of the staff have spoken at a large number of meetings in various parts of the State and have conducted other forms of extension activities. The extension work of the Department embraced the following: speeches (granges, associations, field), 45; farm inspections and demonstrations of practical work (pruning, spraying, and the like), 25; miscellaneous activities (State Fair and county fairs, judging work, and the like), 14.

Each year a fruit exhibit is held at the College, both for the education of the students in the Department and in order that the public may obtain an idea of the practical nature of the work required of the students.

The Department is prepared to send a member to inspect fruit farms and advise the owners whenever time permits. The cost of such an inspection is the actual expense involved in making the trip. In addition, the Department will be glad to arrange a pruning and spraying demonstration in any community where there is sufficient demand for such work. Experienced fruit judges will be provided for grange and county exhibits. A talk on the selection of fruit for exhibition purposes may well be given in conjunction with the judging of the fruit. Requests for speakers at various meetings will be met as far as possible. Finally, the Department wishes to encourage inquiries by mail concerning those problems that can be solved without a personal inspection. Such correspondence will be given prompt attention and careful consideration with a view to making the replies accurate, complete, and practical.

RECOMMENDATIONS

There is pressing need for satisfactory storage space. The only storage available is a small room in the basement of the Dairy Building. Not only is this too small, but it is impossible to reduce the temperature in the room sufficiently to preserve fruit. A mechanical storage with one

large room (one thousand barrels capacity) and several smaller rooms for experimental work is needed. It will be necessary in the immediate future to provide a packing house and barn on the pomology grounds, and in connection with these buildings a residence for the foreman of the grounds.

The need of a laboratory for graduate students is pressing. At the present time there are several graduate students in the Department, but there is no place where they can work without interruption.

C. S. WILSON,
Professor of Pomology.

DEPARTMENT OF FORESTRY

HISTORICAL

A professional course in forestry was opened by the Department of Forestry at the beginning of the college year 1912–1913. The establishment of this professional course was not an afterthought in the history of the development of the Department. On the contrary, Director Bailey had had in mind for several years the giving of professional instruction when the Department should be organized; and in the first letter that he wrote to the present head of the Department regarding the taking of the professorship of forestry at Cornell, dated October 13, 1910, he says: "I want to reach the farm forest situation in the State as a part of our regular work. I want at the same time to train professional foresters, and I think that the facilities will be got for it." In the reply to that letter, dated October 15, 1910, the following statement is made: "The two lines of effort (help for the farm woodlot, and the training of professional foresters) which you outline for the future forestry department are both vital. And I hope that Cornell will soon be able to add a third very important line of forest work — a thoroughly equipped forest experiment station at Ithaca, as a part of the Agricultural Experiment Station."

On November 4, 1910, Director Bailey told the writer that he would nominate him for the position of professor of forestry, a position that had been established by the Board of Trustees in the preceding summer. The writer immediately suggested that Professor Roth, the head of the Department of Forestry at the University of Michigan, be asked to come to Cornell as head of the Department and start the professional course at once. Director Bailey agreed to the plan and said he would do his best to carry it through at once if Professor Roth would agree to come. On November 6, 1910, Professor Roth promised to come, and on the following day our provisional plans for giving a professional forestry course were completed, lacking only the appointments by the Board of Trustees.

The writer's appointment as professor of forestry was made on December 17, 1910. The other plans for the full development of a professional forestry course were necessarily postponed because of lack of funds, and it was not until January, 1912, that it was publicly announced that Professor Roth expected to come to Cornell.

Because it had been necessary to postpone the obtaining of a faculty and equipment for teaching professional students, it was announced that during the college year 1911–1912 no professional instruction would be given. This announcement was made in a mimeographed circular dated August 14, 1911, which was used in answering correspondents. The

circular states: "The courses in forestry to be given the present year . . . . . are not planned for students intending to make forestry a profession, and do not lead to a forestry degree." The organization of professional instruction was postponed, not abandoned.

In January, 1912, the Department began writing to prospective students that the professional course would open in the fall of 1912. The Announcer of the College of Agriculture for February, 1912, stated that Professor Roth was to come to Cornell, and the issue for March, 1912, announced the five-years professional forestry course. A little later Professor Roth decided to remain at the University of Michigan. The writer therefore continued in charge of the Department at Cornell and made the detailed plans for the professional course.

FACULTY

The faculty of last year (consisting of Professor Walter Mulford and Assistant Professor John Bentley, jr.) was continued, and during the year two full professors were added — Professor S. N. Spring, who came to Cornell at the beginning of the college year in September, 1912, and Professor A. B. Recknagel, who began his work on February 1, 1913.

EQUIPMENT

Ground was broken for the Forestry Building in the fall of 1912. Construction was commenced in the spring of 1913 and is making satisfactory progress. In the spring of 1913 the State appropriated $20,000 for equipping the Forestry Building.

During the year a new tract of university land, suitable for forest plantations, was placed in charge of the Department. This comprises about 150 acres of open land around the proposed reservoir site near Varna. A small woodlot, purchased during the year, has also been added to the previous equipment of woodlots. The forest nursery has been somewhat enlarged, and the collection of demonstration material for classroom use is progressing steadily.

In February the Department moved from its previous quarters in the basement of the Main Building, to the Home Economics Building, where the Department of Home Economics has courteously loaned it the use of three offices, a laboratory, and a classroom.

TEACHING

Seventeen courses of instruction were given during the year, as follows: first term, seven; second term, seven; Winter Course, one; Summer School, two.

The number of students registered in these courses was as follows:

Course	Subject	Term	Number of hours credit	Number of students registered
1	Farm Forestry	1	2	43
1	Farm Forestry	2	2	37
2	Elements of Forestry: Mensuration, Utilization, and Management	1	3	56
3	Elements of Forestry: Silviculture	2	3	77
6	The Field of Forestry	1	2	32
8	Wood Technology	2	2	24
9	Forest Utilization	2	4	8
11	Forest Mensuration	2	5	13
13	Timber Trees and Forest Regions	1	3	23
14	Silviculture: Forest Ecology	1	3	17
15	Silviculture: Natural Reproduction and Care of the Forest	2	3	9
16	Silviculture: Forest Planting and the Forest Nursery	2	3	14
18	Forest Protection	1	2	35
19	Forest Policy, Forest Law, and History of Forestry	1	2	24
	Total	......	39	412
16	Farm Forestry (Winter Course)	......	......	47
A	The Farm Woodlot (Summer School)	......	2	6
B	Forests and Forestry (Summer School)	......	2	16
	Total (all courses)	......	......	481

One student received the degree of Master in Forestry in June, 1913 — this being the first advanced degree in forestry that has been awarded at Cornell.

The number of freshmen who entered for the professional forestry course is not known, as these students take the regular course prescribed for all freshmen in the College of Agriculture and do not need to report to the Department of Forestry until the beginning of the sophomore year. In this first year of professional instruction, forty-three students entered the five-years professional course with advanced standing (as sophomores, juniors, seniors, and graduate students).

INVESTIGATION

Over thirty acres of experimental and demonstration plantations (forty thousand trees) were planted on land assigned to the Department. Experiments started in the nursery during the year include tests of the effects

of density of stand in coniferous seed beds; tests of the best age at which to transplant coniferous seedlings; and attempts to root various tree species from cuttings. Work was begun on two experiments in thinning in timberland, and on two experiments in natural reproduction of the forest. Two permanent silvicultural sample plots were established near Ithaca.

EXTENSION

As yet the Department has never had a member of its staff especially employed for extension work, nor one who has been free to devote much time to that work. However, the following extension work was done by various members of the departmental staff during the year 1912–1913, at such times as they could find to devote to the work without detriment to their regular task of teaching.

Seven lectures on forestry were given outside of Ithaca. Fourteen lectures on forestry were given at Ithaca during Farmers' Week, and a departmental exhibit was shown. The second and third lessons were published in the Farm Forestry Series of the Cornell Reading-Course for the Farm. Fourteen examinations of forest land were made for private owners in accordance with the standing offer to make an examination of woodland or of land to be planted, the only expense to the owner for the examination and for a report being the necessary traveling expenses of the Department's representative. Exclusive of circular letters the departmental correspondence numbered three thousand letters, many of which were in connection with extension work. The Department had an exhibit at the State Fair, with three men in charge. The same exhibit was sent to the Rochester Industrial Exposition.

RECOMMENDATION

The Department has urgent need of a tract of several thousand acres of forest land. Such a college forest is needed (1) as a forest experiment station; (2) as a demonstration forest, for the purpose of illustrating the various possible methods of managing forest lands; (3) as a place in which to give forestry students a thorough drill in woodsmanship and in working at various practical operations in the forest.

In order to be really efficient, a college forest should include non-agricultural open lands suitable for reforesting, second-growth timber of various ages, and some tracts of mature timber that could be gradually harvested in order to illustrate logging methods. A satisfactory tract with all these conditions represented cannot be procured for less than $75,000.

WALTER MULFORD,
Professor of Forestry.

DEPARTMENT OF ENTOMOLOGY

TEACHING

The courses of lectures and of laboratory work were given as listed in the Announcement of the College, and were well attended.

There was a marked increase in the number of students in the Department. The total number of registrations in classes during the first term of the year was 1437, of which 1357 were by undergraduates and 80 by graduate students. Of these registrations 605 were in General Biology; 466 in The Farm; 179 in General Entomology; 63 in Animal Parasites and Parasitism; and 124 in more advanced courses.

Since many students took more than one course, the number of students taking work in the Department was considerably less than the total number of registrations; the number of students was about 975.

INVESTIGATION

The investigations conducted by members of the departmental staff, and by advanced students under the direction of the staff, include a wide range of subjects. Reference will here be made only to those that have been completed and the results published since the last annual report. The more important of these are the following:

J. H. Comstock. The silk of spiders. Proceedings of the Second Entomological Congress, Oxford, 1912.

W. A. Riley. Notes on animal parasites and parasitism.

W. A. Riley. Concurrent infection by five species of intestinal worms, including *Schistosoma mansoni*. Science n. s. **36**: 531–532.

W. A. Riley. Some remarkable discoveries regarding a common household insect. Science n. s. **36**: 865–866.

W. A. Riley. Some sources of laboratory material for work on the relations of insects to disease. Ent. news **24**: 172–175.

W. A. Riley. The so-called aërostatic hairs of certain lepidopterous larvæ. Science n.s. **37**: 715–716.

W. A. Riley. Buchner's studien an intracellularen symbionten. Science n.s. **38**: 233–234.

Glenn W. Herrick. The larch case-bearer. Cornell Univ. Agr. Exp. Sta. Bul. 322:37–56.

Glenn W. Herrick. Control of two elm-tree pests. Cornell Univ. Agr. Exp. Sta. Bul. 333: 489–512.

C. R. Crosby. Notes on *Syntomaspis druparum* Boh. and *Ichneumon nigricornis* Berger. Canadian ent. **44**: 365.

C. R. Crosby. The egg-laying habits of *Adoxus vitis* in France. Journ econ. ent. **5**: 384.

C. R. Crosby. The egg of the blackberry leaf-miner. Journ. econ. ent. **5**: 403.

C. R. Crosby. A revision of the North American species of *Megastigmus* Dalman. Ent. Soc. Amer. Ann. **6**: 150–170.

J. C. Bradley. The Siricidae of North America. Journ. ent. and zool. **5**: 1–35.

G. C. Embody. Crustacea. A key to the common genera occurring in fresh water of the eastern United States.

G. C. Embody. Reviews of American fish cultural papers. Oesterreiche fischerei zeitung, January, June, and July, 1913.

O. A. Johannsen. Fungus gnats of North America, Part 4. Maine Agr. Exp. Sta. Bul. 200.

O. A. Johannsen. A tertiary fungus gnat. Amer. journ. sci. **34**: 140.

O. A. Johannsen. Spruce bud-worm and spruce leaf-miners. Maine Agr. Exp. Sta. Bul. 210.

O. A. Johannsen. Potato flea-beetle. Maine Agr. Exp. Sta. Bul. 211.

O. A. Johannsen. *Macrobrachius* in America. Ent. news **25**: 228.

Robert Matheson. The Haliplidae of North America. New York Ent. Soc. Journ. **20**: 156–193.

John Thomas Lloyd. Coca, "the divine plant of the Incas." Amer. Pharm. Ass. Journ. **1913**: 3–14.

J. F. Illingworth. A study of the biology of the apple maggot (*Rhagoletis pomonella*), together with an investigation of methods of control. Cornell Univ. Agr. Exp. Sta. Bul. 324: 125–188.

J. F. Illingworth. Cherry fruit-flies and how to control them. Cornell Univ. Agr. Exp. Sta. Bul. 325: 189–204.

D. E. Fink. The asparagus miner and the twelve-spotted asparagus beetle. Cornell Univ. Agr. Exp. Sta. Bul. 331: 409–436.

C. P. Alexander. Fifteen papers on crane-flies, Tipulidae, in entomological journals.

EXTENSION

The extension work of the Department during the past year has been conducted by Professors Herrick and Crosby. Numerous visits were made to farms, and consultations were held with the owners in regard to the control of insect pests. An exhibit of injurious insects was made at meetings of the state horticultural societies, at the State Fair, and at several county fairs. This exhibit shows the various stages of the more important insect pests and the nature of the injury produced; the method of control also is briefly indicated. A representative of the Department always accompanies the exhibit and is available for consultation with persons interested.

RECOMMENDATIONS

As stated in the departmental report of last year, the time has come when it is impossible to conduct the work of the Department in a satisfactory manner in the rooms at its disposal. Nearly one thousand students are now taking work in the Department, and many of these are taking two or more courses. The writer therefore recommends that steps be taken to secure the erection of the proposed building for this Department at the earliest possible moment.

It is recommended also that provision be made, as soon as practicable, for establishing courses in bee-keeping. This important phase of entomological work is entirely ignored by the educational institutions and experiment stations of the State. There are thirty thousand bee-keepers in the State and the value of the annual production of honey is over two million dollars; it might be made much more. There is a strong Bee-Keepers' Association in the State. The students of the College have asked for instruction in this branch of entomology, which is undoubtedly a legitimate and important field of work.

J. H. COMSTOCK,
Professor of Entomology.

DEPARTMENT OF DAIRY INDUSTRY

TEACHING

Regular courses.— One new course has been added to the work of the Department during the past year. This is Course 21, Dairying for the Farm Home, designed for students in home economics.

The total number of regular and special students who took work in the Department during both semesters was 680. These students were distributed in the different courses as follows:

Course	Subject	Number of students registered
1	Milk Composition and Tests (given both semesters)	233
2	Butter-making	34
3	Cheese-making	18
4	Elementary Bacteriology	39
6	Market Milk and Milk Inspection	122
7	Advanced Testing	13
8	Dairy Bacteriology	15
9	Advanced Butter-making	14
10	Fancy-cheese and Ice-cream Making	13
12	Seminar (given both semesters)	23
13	Research (given both semesters)	15
14	General Agricultural Bacteriology	36
15	Bacteriology for the Home (for students in home economics)	35
16	Milk Composition and Tests (for special students only)	22
18	Butter-making (for special students only)	13
19	Advanced Cheddar-cheese Making	4
21	Dairying for the Farm Home (for students in home economics)	6
	Graduate students	25
	Total	680

This is an increase of 24 per cent for this year over the students enrolled last year.

Winter-course instruction.— There were 87 students enrolled this year in the regular twelve-weeks Winter Course in Dairy Industry. In addition to these, 101 students in general agriculture elected the course in farm

dairying. This makes a total of 188 winter-course students who took work in the Department; and this number, added to the 680 regular and special students, makes a grand total of 868 students in the Department during the past year.

Creamery-managers' course.— This course, lasting for one week, is designed only for those who are managers of dairy plants and who have had considerable experience in dairy work. Entrance to the course presupposes a fundamental knowledge of the principles underlying dairy industry. Nine men were registered in this course last year.

Summer session.— Only one course was given during the summer session this year. This course was the one corresponding with course 1, given during the regular college year. Seventeen students were enrolled. Another general course in dairying was scheduled, but, due to a conflict with chemistry, so few students registered for it that it was abandoned.

Changes in departmental staff.— The following changes took place at the beginning of the fiscal year, October 1, 1912: H. E. Ross, advanced from Assistant Professor to full Professor; H. C. Troy, appointed full Professor; H. M. Pickerill, advanced from Assistant in Butter-making to Instructor in Dairy Bacteriology; T. J. McInerney, advanced from Assistant to Instructor; Miss Elizabeth F. Genung, appointed Assistant in Dairy Bacteriology.

During the winter W. L. Markham was employed to assist in the extension schools.

INVESTIGATION

The investigative work conducted by the Department during the past year is as follows:

1. *Cow-testing-association work.*— This is a continuation of the work outlined in previous reports. The Cow-testing Association is prosperous and is beginning to show results in that better cows are being kept by patrons of the Department. There is not an increase over last year in the number of cows in the association, but there is a healthy interest in the work of the association and it is recommended that the work be continued. It is to be hoped that when the poor cows now in the various herds are disposed of and better ones take their place, the good cows will form a basis for building up larger and better herds.

2. *Market-milk inspection.*— This work is done in cooperation with the city board of health; its object is to improve the city milk supply of Ithaca. The work is of great value to the Department, keeping it in touch with milk-inspection work and furnishing valuable data for teaching this branch of dairy industry.

3. *Publications.*— During the past year the following experiment station

bulletins and reading-course lessons have been published by members of the Department:

W. W. Fisk. A study of some factors influencing the yield and the moisture content of cheddar cheese.

Lois W. Wing. Milking machines: their sterilization and their efficiency in producing clean milk.

E. S. Guthrie and W. W. Fisk. Propagation of starter for butter-making and cheese-making.

H. E. Ross. Composition of milk and some of its products.

The following bulletins are in press and will soon be ready for distribution:

E. S. Guthrie and H. E. Ross. Distribution of moisture and salt in butter.

H. E. Ross and T. J. McInerney. The Babcock test, with special reference to testing cream.

The following pieces of investigative work are nearly finished and will soon be in shape to offer for publication:

Methods of making some of the fancy cheeses.

Evaporation of water from print butter in storage.

Metallic flavor in butter.

The following pieces of investigative work are being conducted by various members of the Department. Probably the results of some of these will be ready for publication sometime during the coming fiscal year; others may require more than one year of work for their completion:

Comparative methods of cooling milk.

The comparison of presumptive tests for *Bacillus coli* in milk.

The bacteria of spoiled canned peas and beans.

A quantitative test for water in cheese.

A study of the composition of buttermilk.

Factors affecting the richness of cream from hand separators.

EXTENSION

The cow-testing-association work may be included under the head of extension as well as under investigation. It partakes of the nature of both. It is of the nature of extension work in that the Department is endeavoring to aid dairymen to eliminate poor cows from their herds.

The extension instructor for the Department, H. L. Ayres, has visited about the same number of dairy plants and of winter-course students as he did in the previous year. This branch of the extension work of the Department is very important. It enables the Department to keep in touch with its former students and help them out of many of their difficulties, thereby making them more efficient and more of a credit both to

themselves and to the Department. During the past fiscal year, twenty addresses were given by various members of the Department before dairy meetings and farmers' meetings. In addition to this, W. L. Markham attended eleven extension schools and gave instruction in dairy work. Six fairs, including the State Fair, were attended, with an exhibit, by different members of the Department, and the Department was represented with an exhibit at the State Dairymen's Convention.

Educational scoring of dairy products.— This work has been continued the same as in previous years. Butter- and cheese-makers and milk-producers in any part of New York State may send samples of their products to the Department once each month, to be scored for quality. Certain detailed reports are required of those sending such samples. The Department also requires its former winter-course students who are working for a Certificate of Proficiency to send twelve consecutive monthly samples of their product, for scoring. This has two or three advantages: it enables us to select those who really are deserving of a Certificate of Proficiency, and also to help our former students to improve the quality of their product.

Correspondence.— During the past year over six thousand letters have been written by members of the Department, and no small part of these may be classed under extension work. The Department is constantly in receipt of letters from all parts of the State, asking questions concerning the business of dairying. These letters are from cheese factories, butter factories, market-milk plants, and milk-producers, and the Department feels that by careful response much good is accomplished.

RECOMMENDATIONS

One general recommendation for the Department of Dairy Industry is that it be furnished with more room in which to carry on its work. This is true of every branch of the Department. The course in dairy bacteriology is especially crowded, and much difficulty is experienced in furnishing our graduate students with sufficient room in which to carry on their special problems. There is need of special apparatus for teaching the condensing of milk, and it is to be hoped that both room and machinery for this work can be furnished sometime in the near future. This branch of work is of constantly growing importance in dairy industry. Facilities for manufacturing milk sugar and casein are also needed.

W. A. STOCKING, JR.,
Professor of Dairy Industry.

DEPARTMENT OF ANIMAL HUSBANDRY

TEACHING

The following table shows the registration in the various courses in this Department for the two terms:

Course	Subject	Number of students registered	
		First term	Second term
1	Principles and Practice of Feeding Animals	155	264
2	Principles of Animal Breeding	151	213
5	The Horse	....	86
10	Dairy Cattle	23	....
11	Beef Cattle, Sheep, and Swine	15	....
15	Advanced Course in Principles of Feeding	....	48
16	Advanced Course in Principles of Breeding	14	13
17	Advanced Stock Judging	25	15
		383	639
1	Feeds and Feeding (Winter Course)	333	
2	Breeds and Breeding (Winter Course)	121	
A	Principles and Practice of Feeding Animals (Summer School)	22	
B	Principles of Animal Breeding, and Elementary Judging (Summer School)	20	
		496	
	Total number receiving instruction, 1518		

The students registering in the various classes, in the main, made very satisfactory progress. The number of failures was smaller than in previous years.

INVESTIGATION

The investigative work of the Department is largely of a continuous nature, the more important subjects indicated in the report made to the Director one year ago having been continued although it has not seemed wise to publish any results in bulletin form. For the coming year, in addition to those topics already under investigation, it is planned to make some careful experiments along the line of the possibility of rearing and developing a calf under conditions where milk is not available or is available only in limited quantities.

EXTENSION

The extension work of the Department has been rather large in amount, although a special officer for this work was available for only a part of the year. The Department was represented in a large proportion of extension schools; and six district and county fairs, in addition to the State Fair, were furnished with exhibits. About fifty lectures were given and meetings attended by members of the staff of the Department. An important part of the extension work of the Department is in the supervision of the records of pure-bred cattle. During the past year official records of 2313 Holstein cows were supervised continuously for seven or more days; these represented about four hundred owners, scattered in all parts of the State. In addition, stated monthly inspections of two days each were made for fifty owners, representing the Ayrshire, Brown Swiss, Devon, Guernsey, Holstein, and Jersey breeds. At the present time the records of 516 cows are being supervised in this way, distributed among the various breeds according to the following table:

Breed	Number of owners	Number of cows
Ayrshire	10	144
Brown Swiss	2	6
Devon	1	6
Guernsey	11	88
Holstein	13	73
Jersey	13	199
Total	50	516

The appointment of Professor H. A. Hopper as extension teacher in animal husbandry is expected to materially strengthen the work of the Department for the ensuing year.

RECOMMENDATIONS

The completion of the new buildings for the Department will greatly increase the facilities for the work and will make possible development along lines of work that have hitherto lain dormant. The work in sheep and swine husbandry should be materially strengthened, both in increasing the herds and flocks and in providing instructors; and it will be necessary to provide additional instruction in the farm curing of meats, which will require the services of a trained expert.

H. H. WING,
Professor of Animal Husbandry.

DEPARTMENT OF POULTRY HUSBANDRY

The work of the Department falls naturally into four distinct divisions — teaching, investigation, extension, and administration. It has been the policy of the Department to endeavor to develop these four divisions equally; that is to say, approximately one fourth of the money and effort has been put into each division. It is believed that in this way the most efficient work for the State can be accomplished.

INSTRUCTION

This year, for the first time, the Department has been able to occupy the new Poultry Husbandry Building. As a result of the improved facilities, there has been a marked increase in the number of students taking courses in Poultry Husbandry. This is shown in the following table, which gives the number of university hours taught each year from 1903 to 1913 inclusive:

	1903–1904	1904–1905	1905–1906	1906–1907	1907–1908	1908–1909	1909–1910	1910–1911	1911–1912	1912–1913
Regular and special courses	74	339	158	474	527	589	329	620	915	1,477
Winter Poultry Course	....	225	540	690	690	780	825	810	825	2,124
Winter Courses, elective	54	60	80	64	66	62	66	108	120	196
Summer School	....	....	....	.....	.....	.....	.....	.....	33	165
Total	128	624	778	1,228	1,283	1,431	1,220	1,538	1,893	3,962

It will be seen that this year there has been an increase over last year of 2069 university hours taught — an increase of 109 per cent.

The number of students taking various courses in poultry husbandry in 1911–1912 and in 1912–1913 was as follows:

	1911–1912	1912–1913
Regular and special students	183	370
Winter Course in Poultry Husbandry	56	118
Students in other winter courses electing poultry husbandry	60	98
Summer School	50	110
Total	349	696

Owing to the fact that the old poultry plant was moved during the year to the poultry farm and the new poultry plant in connection with the new building has not been built, it will be impossible to give at present any of the practice courses in feeding, fattening, and brooding.

The marked increase in registration in poultry husbandry is due in large measure to two causes: (1) this year, for the first time, the Department has been able to offer suitable facilities as regards buildings and equipment; and (2) because of these new facilities, it was possible to give, for the first time, a three-hours course in farm poultry, and to accept 118 students in the Winter Course.

The Department, this year as heretofore, has laid special stress on the importance of the laboratory and practice types of instruction, in which a large number of printed outlines and a large supply of materials are required. It is estimated that the Department has used for instructional purposes during the year 25,536 multigraphed or mimeographed sheets, approximately 2500 fowls for killing and judging dressed poultry and anatomy practice, and 2250 dozen eggs. This makes a very heavy drain on the maintenance funds of the Department, inasmuch as no laboratory fees have ever been charged except to winter-course or summer-school students. We believe, however, that the expenditure is abundantly justified in view of the results obtained.

INVESTIGATION

The Department has conducted investigations during the year as follows:

1. A comparison of different methods of feeding.
2. Free range, or outdoor liberty, in winter in comparison with confinement within the house.
3. A study of the inheritance of egg production.
4. A comparison of large grass yards for poultry with small bare yards.
5. A comparison of egg production and constitutional vigor of hen-hatched chickens with those of incubator-hatched chickens.
6. Breeding to improve the size, shape, and color of market eggs.
7. An incubation experiment comparing several methods of keeping eggs before incubating them.
8. The comparative value of animal protein and mineral nutrients in the feeding of fowls for egg production.
9. Sex influence on the inheritance of egg production.
10. Sex influence on the inheritance of constitutional vigor.
11. A study of types in poultry-house construction.

In the investigative work of the Department 847 fowls have been used.

One bulletin — 327, "Methods of Chick-feeding" — and two circulars — No. 14, "Working Plans of Cornell Poultry-houses," and No. 16, "The Improved New York State Gasoline-heated Colony-house Brooding System" — have been prepared and published during the year.

The investigative work is now conducted entirely at the new experiment plant on the poultry farm at Forest Home. Here, for the first time, the flocks are kept under favorable conditions as regards the amount of land available for range and as regards freedom from interruption of the work, being far removed from the distractions arising from close contact with the teaching enterprise.

EXTENSION

Extension work away from the College.— In the following table may be seen the number and kinds of extension activities of the Department for the past four years. It will be seen that in 1912–1913 four hundred and thirty-three appointments were filled by members of the departmental staff, which is an increase of one hundred and twenty-seven over the previous year.

	1909–1910	1910–1911	1911–1912	1912–1913
Farm visits to assist in selecting breeding stock, grading eggs, laying out plans for poultry farms, and the like.	17	62	180	255
Speaking engagements in connection with poultry shows, granges, Young Men's Christian Associations, farmers' institutes, extension schools, farm trains, fairs, and the like......	109	79	92	136
Educational exhibits staged in connection with poultry shows, agricultural fairs, Young Men's Christian Associations, farm trains, extension schools, and the like...............	18	23	34	42
Total..........................	144	164	306	433

Three persons gave almost their entire time, during the four winter months, to various types of extension work in connection with poultry shows, extension schools, Young Men's Christian Associations, and similar gatherings.

Correspondence.— The correspondence of the Department has increased at the usual rate, as is shown below:

	1908–1909	1909–1910	1910–1911	1911–1912	1912–1913
Letters	7,088	7,470	7,364	8,456	9,304
Form letters	....	....	2,393	2,141	2,198
Total	7,088	7,470	9,757	10,597	11,502

Poultry survey.— The postal-card poultry survey has progressed satisfactorily during the year. On September 30 the survey map and card index indicated that replies had been received from 972 poultrymen in the State, who report as follows:

Number of farms	Number of fowls
583	1 to 200
238	201 to 500
100	501 to 1000
35	1001 to 2000
16	2001 or more

This survey enables us to keep in close touch with many of the best poultrymen of the State, to whom we send poultry literature and with whom we cooperate in other ways.

Cooperative marketing association.— The cooperative-marketing-association project, which was organized during the year and which has now been in operation for about seven months, developed even more satisfactorily than had been anticipated. The Department has supervised the organization of the Ithaca Producers' Association. This project is under the immediate supervision of E. W. Benjamin, an instructor in the Department, who reports that the association has handled the poultry and eggs produced by 168 patrons within a radius of approximately ten miles of Ithaca. The number of eggs handled by the association for its patrons from March 1 to September 30, 1913, seven months, was 31,511½ dozens, equal to 1050 cases of 30 dozens each, or approximately two and one half carloads. The amount of poultry handled during the same time was 6538⅓ pounds, or approximately three and one quarter tons. The total net returns to the patrons were $7753.86. It is

estimated that the patrons have been aided in receiving about three cents per dozen more for their eggs, and two cents per pound more for their poultry, than they would otherwise have been likely to receive; or, expressed in money value, the patrons have received about $130 more for their poultry and $945 more for their eggs, or a total of $1075, than they would otherwise have been able to get by the usual methods. This increase in profits is due primarily to greater care in testing, grading, and packing, which has resulted in higher prices' being received. The educational value of the project is a stimulus to greater production of a better quality of poultry and eggs. More systematic care and accounting is of even greater advantage to the patrons than the increase in their net profits due to the sales. The project is of benefit not only to the producer, but also to the consumer, and has resulted in obtaining close cooperation with persons who otherwise might not be in touch with the College.

Extension work in Chemung county.— One of the very profitable extension activities of the year is the work that W. G. Krum, an assistant in the Department, has been doing in cooperation with the Business Men's Association of Elmira, as is indicated by a report of one week's work in connection with the schools and homes of Chemung county. During that week twenty lectures on poultry husbandry were given to audiences showing a total attendance of 1267. Thirteen farms were visited and forty-three persons were given advice. The lectures and demonstrations were given primarily with a view of enabling the boys and girls in the schools to more successfully handle flocks of poultry, to keep accurate records, and to pass the examinations that were required by the Business Men's Association. This association gave to the contestants, as a reward for good work, specially designed poultry buildings and settings of eggs. This work is emphatically teaching children "in terms of their daily lives," and could be extended with profit to many counties of the State.

Farmers' Week.— During Farmers' Week, for the first time, the experiment was tried of giving systematic instruction in laboratory practice in the study of the egg, anatomy of poultry, the killing of poultry, and the grading of eggs. For this instruction a laboratory fee of twenty-five cents was charged, with the following result:

Killing, picking, and packing poultry (20 persons).............	$ 5.00
Testing, grading, and packing eggs (38 persons)..............	9.50
Dissection and anatomy of poultry (16 persons)...............	4.00
Study of the egg (8 persons)..................................	2.00
Total.................	$20.50

As an indication of the number of persons who are reached during Farmers' Week, the following tabulation of the attendance at the new Poultry Husbandry Building during last Farmers' Week is given:

	Attendance
Lectures, twenty-six, thirty minutes to an hour each	4,107
Dedication exercises, two sessions	525
Laboratory exercises, thirteen	315
Poultry Conference, one session	50
Poultry Association session, four lectures	135
Poultry contests, four	170
Total	5,302

ADMINISTRATION

The principal items of the inventory taken on July 1, 1913, in comparison with those in each of the five years previous, are shown below. The very large increase in the valuation of land, buildings, and equipment is due to the fact that in the figures for this year are included the new Poultry Husbandry Building (costing $90,000) and equipment (costing $15,000), and thirty acres of land recently purchased and added to the poultry farm.

	1908	1909	1910	1911	1912	1913
Land	$ 1,000	$ 1,000	$ 3,500	$ 3,500	$ 3,500	$ 7,100
Buildings	5,876	6,248	6,416	6,438	7,225	102,850
Stock	2,696	2,034	3,400	3,098	4,264	4,795
Equipment	3,569	4,676	6,496	6,975	7,471	13,580
Total	$13,141	$13,958	$19,812	$20,011	$22,460	$128,325

It is seen that the Department shows an inventoried valuation for land, buildings, stock, and equipment of $128,325, which includes fifty acres of the eighty-acre poultry farm on which rental is paid.

Improvements.— The material improvements of the year include the moving of the old poultry plant to the poultry farm at Forest Home, and the acquisition of a permanent water supply for the farm. The poultry farm, as it is now organized, provides for the growing of field crops for the poultry, land for rearing about four thousand chickens annually on free range, the keeping of all flocks for investigative purposes, and quarters for the stock for instructional purposes during the summer.

The amount of stock on the poultry farm for the past six years is shown below. About half of the mature stock is devoted to experimental purposes, and the balance is used for instruction.

	1908	1909	1910	1911	1912	1913
Old	829	739	1,045	1,495	1,561	2,498
Young	3,298	3,683	2,803	3,031	3,502	5,320
Total	4,127	4,422	3,848	4,526	5,063	7,818

New buildings.— During the year the Department has designed auxiliary buildings to be erected on the plateau to the north, east, and west of the new Poultry Husbandry Building. These structures are to be built with the appropriation of $25,000 recently made by the Legislature. The buildings are to form the outdoor laboratories and are to be used entirely for instructional purposes. The plant will include a centrally located feed-and-appliance building, a fattening house, a breed-observation house, two brooder houses, and houses to contain flocks for egg production.

This has been the most eventful and the most prosperous year in the history of the Department.

JAMES E. RICE,
Professor of Poultry Husbandry.

DEPARTMENT OF FARM MECHANICS

TEACHING

During the past year no radical change has been made either in the courses offered or in the method of teaching them. The number of students receiving instruction from the Department is given in the following table:

Course	Subject	Number of students registered	
		First term	Second term
3	Farm Mechanics	150	122
4	Dairy Mechanics	......	40
20	Farm Engineering	60	135
28	Advanced Work in Farm Engineering	......	11
7	Farm Mechanics (Winter Course)	125	
27	Farm Engineering (Winter Course)	64	
	Total registration in 1912–1913, 707.		

INVESTIGATION

The investigations of simplified sewage-disposal systems have been continued during the past year, in connection mainly with extension work. The installations at Lodi, at Taughannock Falls, and at the county almshouse near Jacksonville, all of which have been completed during the past year, afford valuable opportunity for study.

In farm engineering the operation of the irrigation plant at Brockport is still being studied, and a plant at Charlotte has been designed and installed in cooperation with the Department of Pomology at this College and the Rochester Railway and Light Company. The study of the run-off of a part of the drainage system on the college farm has been delayed for lack of a satisfactory recording mechanism for the drainometer. An improved design is under construction. Much work has been done in the study of difficult engineering problems in drainage, in connection with extension work in farm engineering. The observations on the lasting qualities of different types of drain tile are being continued.

EXTENSION

The Department prepared exhibits for the State Fair at Syracuse and for the county fair at Batavia, special attention being given to sewage disposal, water supply, and types of drain tile. Much individual assistance was given in sewage-disposal problems, both by mail and by personal visits. Disposal systems for the county tuberculosis hospital at Taughannock Falls and for the county almshouse at Jacksonville, after having been approved by the State Department of Health and the Conservation Commission, were successfully installed under the direction of this Department. A private installation at Lodi, using the Cornell sewage switch and dividers, was put in under departmental direction, for the purpose of affording an experimental plant.

The work in farm engineering under Mr. Robb included visits to ten farms in cooperation with the State Department of Agriculture and fifteen visits for this Department. Of these twenty-five trips, eleven were for consultation only, one was for a lecture, and thirteen were for the purpose of making a survey of the property in question, from which surveys a map was prepared in each case. The average length of time required for a consultation trip was two days, while a survey and map involved work for two days to a week or more in each case.

An extensive piece of work now being done under the direction of this Department is the preparation of a complete map of all the college farm properties, with contour lines at one-foot intervals wherever the character of the land will permit and at five- or ten-foot intervals in rough sections.

RECOMMENDATIONS

The Department is greatly in need of larger quarters. At present there is no place where shop work of any kind can be given, and no opportunity is afforded for an exhibition of farm machinery. Both these lines are especially needed, and it is hoped that it may be possible at no very far distant date to provide an adequate rural engineering building.

HOWARD W. RILEY,
Professor of Farm Mechanics.

DEPARTMENT OF AGRICULTURAL CHEMISTRY

TEACHING

During the regular college year ten courses of instruction were given, in which 686 students were enrolled. Four courses were given in the summer session, with an enrollment of 51 students. In addition to this, 298 winter-course students received instruction. The work was done by three teachers — Professor Cavanaugh, Assistant Professor Cross, and Mr. Rice.

INVESTIGATION

Very little investigation is being done by the Department. This is due to inadequate facilities. The Department at present has not sufficient men on its staff, nor room for the conducting of extensive problems of investigation. Its work is therefore confined to the smaller problems in connection with the research of a few graduate students.

EXTENSION

In the analytical laboratory four hundred and five samples have been examined. Some of this work has been done for the different departments of the College, but the greater part of it has been done for farmers of the State. The work consists of the examination of feeds, fertilizers, soil, and the like.

Lectures before different organizations, including extension schools, have been made by Professor Cavanaugh and Assistant Professor Cross. Mr. Rice has been in attendance at county fairs, with exhibits, for five weeks.

RECOMMENDATIONS

The following recommendations are made:

1. That at least $500 in addition to the regular maintenance be appropriated for the purchase of special apparatus to be used in teaching. This Department is at present dependent on the Department of Chemistry of the College of Arts and Sciences for the use of much apparatus used in teaching. As both departments grow, this Department feels more and more the lack of sufficient necessary apparatus for the proper instruction of its students.

2. That the staff be increased by two men — a chemist, of the grade of instructor, for work in the analytical laboratory; and an assistant on the teaching force.

GEORGE W. CAVANAUGH,

Professor of Chemistry in its Relations with Agriculture.

DEPARTMENT OF LANDSCAPE ART

TEACHING

During the year 1912–1913 the instructing staff, in addition to the writer, was composed of E. Gorton Davis, Assistant Professor; E. D. Montillon, Instructor; J. R. Van Kleek, Assistant; and C. E. Hunn, Foreman of Grounds.

Previous to the past year the departmental work has been conducted in rooms provided separately by the colleges of Agriculture and Architecture — the business and administrative work in an office in the Main Building of the College of Agriculture, and the drafting and lecture work in rooms in White Hall kindly offered by the College of Architecture. It seemed best at the beginning of this year to remove entirely to the College of Agriculture, because adequate room was lacking in White Hall and also because it seemed best for a department of the College of Agriculture to be housed in closer proximity to other departments of the College. In making the change an excellent working atmosphere and fine library privileges were lost. These losses were compensated for, however, in the value gained by more centralized quarters and by consequent closer control over, and cooperation with, the students and the allied departments. Lack of proper library facilities was somewhat offset by the transferring of many of the more important books on landscape architecture from the general and architectural libraries to shelves in the office and the new drafting room of the Department; these, together with pamphlets, catalogues, and other data, forming the nucleus of a departmental library.

With administration and instruction under one roof it has been possible for the Department to do much better work than heretofore, and the students have profited by the change.

As was stated in the departmental report for last year, the curriculum is under constant study, due to the possibility of improvement that comes from experience and to the demands arising because better-prepared and more advanced students are coming to the College for instruction. The work is being constantly better understood; it is no longer a novelty to be tried by any pupil who may perchance think he would like to be a landscape designer, but has become the serious work of the student who fully understands its requirements and possibilities.

The Department is teaching a most intangible subject, consequently progress has been exceedingly difficult. Appreciation and knowledge of landscape art is not readily inculcated in the average mind. There must

be a predisposition for the work and an innate or ingrained love for and understanding of it. Provided these are present, the foundation is secure and understanding and ability can be created; otherwise it is quite useless to expect results.

Town- and city-planning

The Department has not yet offered a special course in town- and city-planning, but has touched on the subject in other courses. The increasing demand for instruction in this particular branch of the work, however, is such that the Department will soon be compelled to give adequate attention to it. Village-, town-, and city-planning is no longer to be the result of haphazard practices; trained intelligence is now demanded for this work. The arrangement and planning of the land for human use, habitation, and convenience, be it city or farm, is no longer merely a matter of æsthetics but is a vital question in social economics. Life in its most fundamental aspects is largely determined by environment. The arrangement of the village and town, the city, or the grounds of public institutions, is now recognized as quite as dominant a factor for good as is the school in the town, the laws of the city, or the correctional work of the reformatory or the asylum which may have been subjected to a study of its landscape surroundings.

When this work in town-planning and civic design is offered, it should no doubt be in the form of advanced work leading toward a master's degree, at least in the beginning. Later, perhaps, a general course might be offered during undergraduate work, the student being allowed, possibly in his junior and senior years, to arrange his work with special reference to the above subjects.

Special lectures and trips

During the past year the Department has not been able to provide for the students either trips of inspection or special lecturers, owing to lack of funds. The money at the disposal of the Department has been spent for much-needed equipment. It would be advantageous if a definite and proper sum of money could be set aside by the Department for the engagement of visiting lecturers and practitioners, who might not only give more advanced thought to the students but also interpret their varying points of view. Such visiting instructors should be of general value to the College, all of whose students might well profit by the lectures and criticisms. One visiting lecturer of sufficient renown to make his visit of general interest was engaged during the year — Ewart G. Culpin, of London, England, Editor of "Garden Cities and Town Planning" and one of the foremost men in the town-planning movement abroad. His lecture on the general subject of town-planning was most instructive, not only to our students but to a general university audience; and the

same lecture, given before all the most important universities of this country and Canada, has no doubt done more to interest this country in the importance of landscape art than has anything else during the past ten years. In a recent number of "Garden Cities and Town Planning," Mr. Culpin comments most favorably on the various courses in landscape design in this country, saying that at Harvard, Ann Arbor, and Cornell some excellent and practical work is being done.

INVESTIGATION

In this connection should be mentioned the excellent study made by Professor Davis in the history of landscape design. He has been untiring in his research in the libraries and other fields of data, not only in this country but abroad as well. He has just returned from a visit to England and the Continent, where he went solely in the interest of the Department and whence he brings valuable photographs and data. Mr. Montillon, also, has been giving considerable time to a study of the closer relation of architecture to landscape art, his inquiries helping largely to form the basis of a course of instruction in this particular study.

Our graduate students of the past year were largely concerned with research problems of vital value to us as a department. Two students made fairly complete investigation and study of the possibilities, opportunity, and value of the improvement of the city of Auburn and the village of Rose, New York. The results of this study not only have been made departmental record, but also have been submitted to the authorities of the city and the village studied.

EXTENSION

Even though there has been little money at the disposal of the Department for work of this nature, considerable extension work has been accomplished.

In the report of last year mention was made of the fact that the Department was dealing directly with the Fiscal Supervisor of State Charities at Albany, and that a definite beginning had been made toward the development and care of the grounds about several institutions under his charge. Much further work has been done during the past year along this line, as may be seen from the last Annual Report of the Fiscal Supervisor of State Charities. The following is quoted from the Supervisor's opening page, under the caption "Landscape Accomplishments of the Past Year":

> Various scattering attempts have been made from time to time toward beautifying the institutional building surroundings. This beautification has been attempted but

never completely accomplished through the spasmodic employment of landscape artists. This now-and-then employment, although costing considerable money, has never crystallized into any definite landscape development plan.

It was to attain this result that the spring of 1912 saw the Department approach the Dean of the New York State College of Agriculture, Mr. Liberty Hyde Bailey, and ask for loan of a landscape artist. Dean Bailey very kindly permitted the Department to appropriate Assistant Professor E. Gorton Davis of the Department of Landscape Art, of Ithaca. Professor Davis has, for mere traveling and board expenses while away from Ithaca, accomplished most valuable work at our institutions. This has meant a saving of a large amount of money and has permitted these institutions to embark upon the working out of a definite landscape scheme.

The Department appreciates the courtesy of the New York State Agricultural Officials in this matter, and takes opportunity to express its thanks.

Considering the possibility of the great social and educational value to be gained from this and similar extension work — for example, the landscape and architectural improvement of the rural schools — it seems a great pity that there cannot be a considerable sum of money set aside by the College and the State for just such work, quite as necessary and humanitarian as many other fields of investigation. It is recommended that careful thought be given to this matter. Money should not, and cannot readily, be taken from the general funds of the Department in an amount sufficient to accomplish marked results. Without necessary funds our first duty must be toward the college teaching; and extension work, though ever so small, cannot be attempted at any sacrifice to the immediate teaching work.

Bulletins should be issued regularly in order to properly answer the constant inquiries that are received. Considerable data preparatory to publications of this nature have been gathered during the past year. The Department realizes the great importance of this method of disseminating knowledge, and feels keenly the lack of such publications to date. But the work of organizing the subject matter for these publications, virtually without precedent, has called for much care and time.

EXPENDITURES

Our budget for the past year showed a slight increase over that of the year previous. Our working equipment has been augmented by the addition of a large number of illustrations and slides, together with other data; and much cataloguing and library work has been done and will be continued during the coming year.

COLLEGE PLAN

Much has been accomplished during the past year on the college-plan work. A survey of practically the entire college grounds and farms has been compiled, checked, and made available for use; and a general plan of arrangement for the college properties not only has been completed

but has been accepted by the Agricultural College Council and the University Grounds Committee. The foundation of these plans has involved much time, study, and expense; but the results to date seem most gratifying, especially inasmuch as the work has resulted in the final adoption of a plan of arrangement of the agricultural campus. There is still much to be done on these plans, all of which must be carefully detailed.

ARBORETUM

While a good beginning was made two years ago toward the establishment of an arboretum, and its development and progress have been constant during the past year, it was necessary, due to the lack of proper help in the Department, that efforts be confined largely to the assembling and propagating of plant materials for future use. No actual arboretum planting could be done, the reason for this being the deferred acceptance of a more or less general plan of arrangement of the college grounds. This difficulty has now been eliminated. During most of the past year we have been on the lookout for a well-grounded and able man to assume the main responsibility of the planting and plant-material work in our course of study in addition to the work of planning for and establishing an arboretum. Last spring we were fortunate in obtaining the interest and cooperation of Ralph Curtis, of the Arnold Arboretum of Boston, resulting in his appointment as Assistant Professor in Plant Materials. Not only shall we be better able to continue the work incidental to the establishment of the arboretum, but in its planning we shall materially benefit by the experience and advice of Mr. Curtis. Also, the knowledge that he brings to the Department will greatly increase the value of our plant-material courses, which until this year have remained somewhat undeveloped.

NEW BUILDING

During the past year it was decided that the Department should be given the frame building formerly used by the Department of Poultry Husbandry. This building is to be removed to a chosen site and remodeled for the temporary use of the Department, a moderate amount of money having been set aside for the work. Plans and specifications were drawn by Mr. Montillon for the necessary alterations, and it was found that, with the changes as planned, proper and suitable quarters for the Department for at least five years could be obtained. Tenders taken for the work proved too high; consequently the work did not progress and the building was not ready for use this fall. Therefore the Department is still using one of the rooms in the Main Building for administrative work, and newly acquired space in the Dairy Building for drafting and

teaching work. This is both an unsatisfactory and an unfortunate arrangement, again separating our interests although not so much as when space was used in White Hall. Conditions, both for us and for others, are so crowded, and even the inadequate space that we occupy is so badly needed for other work, that it is hoped all possible effort will be made to advance our present building appropriation sufficiently to allow of our new quarters being available at an early day.

BRYANT FLEMING,
Professor of Landscape Art.

DEPARTMENT OF DRAWING

TEACHING

For the past year the number of students taking work in the several courses in the Department of Drawing was as follows:

Course	Subject	Number of students registered	
		First term	Second term
1	Mechanical Drawing	56	54
2	Free-hand Drawing	59	28
3	Applied Drawing	9	18
4	Isometric Drawing	13	....
5	Perspective	5	4
		142	104

Adding the numbers for both terms gives a total of 246, as against 140 for the preceding year. This shows a gain of 75 per cent.

Every graduate of this College should have had a course in mechanical drawing and should be able to read building plans and simple machine drawings. That the general student realizes his need for such knowledge is shown, not only by the increased attendance in these classes, but also by the fact that many students have been prevented from registering in the course because of conflicts with other courses scheduled at the same hours. The present floor space occupied by the Department precludes the formation of additional sections in Mechanical Drawing; also, an increase in sections would necessitate an increase in the teaching force.

Scientific classification, and all judging and scoring, are based on the consideration of relative size, form, color, and position; and free-hand drawing is the only course in which the student makes a study of relative size, form, color, and position as such. Drawing is form study, as are all the morphological sciences; hence its value to the student of science. The courses in free-hand drawing are intended especially to aid the scientific student in his graphic expression of form. It is the aim of the Department, also, to develop in the student an increased appreciation of pictorial art.

The equipment of the Department is being added to, as need arises and funds permit, in the form of artificial fungi, plant models, and mounted insects, birds, and animals for the free-hand courses, and of machine parts and simple demonstration apparatus for mechanical drawing.

INVESTIGATION

While the Department does no investigative work as such, yet constant experiments are being made in order to determine the best materials and methods of graphic expression required by scientific students.

RECOMMENDATIONS

Any recommendations that the Department might be disposed to make would be in the nature of added appropriation. More funds could well be employed, especially for cabinets for storing the students' drawing materials and instruments and for demonstration apparatus and models. Additional funds could also be used in purchasing facsimile reproductions of good paintings, suitably framed, for aiding in the development of the student's appreciation of fine art. A larger teaching force would enable the Department to offer afternoon work in free-hand courses, and, as indicated above, more floor space would make possible additional sections in mechanical drawing.

W. C. BAKER,
Assistant Professor of Drawing.

DEPARTMENT OF RURAL ECONOMY

The Professor in charge of the Department having sabbatic leave of absence for the second half-year, all work other than the answering of letters ceased after the first of February. The sabbatic leave was spent in studying agricultural conditions in Europe, particularly the problems of land tenure and of cooperation.

TEACHING

Again the number of students taking courses in rural economy increased over the previous registration. It was impossible to give the students the attention to which they are entitled. To the Department was assigned as an office an artificially lighted interior room, half as large in area as the one that it previously occupied. Neither instructor nor students could risk their health in such a place, and conferences with students were at a minimum.

INVESTIGATION

No new problems were taken up. Some studies were made with reference to the investigations to be undertaken in Europe.

EXTENSION

The work in extension is still confined to correspondence and to an occasional lecture away from Ithaca. The final preparations have been made for the investigation of cooperation in the State of New York as a basis for extension efforts in the future. With the beginning of the next year the investigation will be under way.

RECOMMENDATIONS

As has been said in every previous report, the greatest need of the Department is for space to accommodate the undergraduate students, to accommodate the graduate students who are now turned away, to give an opportunity to develop the teaching and investigative work, and to provide for work in extension. The space allotted to the Department in the new Auditorium has been seriously encroached upon, necessitating a new plan of division. Although thus provided with at least comfortable offices, no provision has been made to satisfy the needs of the students. The Department needs a whole floor of the size of those in the Main Building, in order to do justice to the students now registered in the courses.

The staff of the Department should be increased by the addition of an instructor for the economic side of the subject, an instructor for the social side of the subject, and an extension man for each of these lines — the first to begin his work on the cooperation problem, for which there is much demand in the State. It is not a matter of the moment to get men for these lines of effort, and in most cases it will be necessary to train the men.

The other needs of the Department are for illustrative material, books, and supplies.

G. N. LAUMAN,
Professor of Rural Economy.

DEPARTMENT OF HOME ECONOMICS

The departmental staff for the year 1912–1913 comprised the following persons:

Two heads of department, one assistant professor on half time, one instructor on full time, one instructor on half time, two student assistants, one extension assistant on two thirds time, manager of cafeteria, one clerk and housekeeper, one housekeeper, and one janitor.

EQUIPMENT

Building.— The Department of Home Economics moved from its old quarters in the College of Agriculture to the new Home Economics Building at the close of the first term of the year 1912–1913. The building was open to outsiders for the first time in February, during Farmers' Week. Although the equipment was most incomplete, the laboratories unfurnished, and many of the floors still unfinished, the Home-makers' Conference was held in the new building and the crowds attending Farmers' Week and the Home-makers' Conference were fed in the cafeteria, which was temporarily opened.

Home Economics Lodge.— No piece of work done by the department proved of greater practical value than the refurnishing and remodeling of the old farmhouse known as the Tailby house and renamed the Home Economics Lodge. The house has been a center of interest to persons studying household problems throughout the State, and it has furnished a useful object lesson to the students in the Department.

The cafeteria.— The cafeteria in the basement of the Home Economics Building has been thoroughly equipped. The object is to furnish meals at as low a rate as possible, taking into consideration the expense of running, cost of food, upkeep of the place, and a reasonable interest on the investment.

Another important object is to offer to the students in the Department a practical knowledge of the serving of large numbers of persons, since that is an important feature in home-economics education. With this in view several women students registered in the Department are employed. They are paid by the hour and they buy their meals as do all other students. The heavier part of the student work is done by men in the University — students who wish to be self-supporting. In addition there are employed for regular work a cook and an assistant, a baker and an assistant, a man to manage the dish-washing, a pot-washer, and a cleaner. An engineer, who is an assistant to the engineer of the College of Agriculture, is employed to care for the machinery, since much of the equip-

ment, including cold storage, is run by power. The cafeteria is in charge of a graduate of the Department.

During Farmers' Week meals were served, with imperfect equipment, to eight hundred to one thousand persons daily. The cafeteria was then closed in order that the equipment might be completed, and was opened again on April 10.

From April 10 to June 18, the number of meals served in the cafeteria was 27,520. During the summer session of six weeks there were served 36,971 meals, making a total of 64,491 meals served since the opening of the cafeteria on April 10, 1913. Up to the beginning of the present year only two meals were served daily, Sundays omitted. There is a demand for serving three times daily, with Sunday serving, for those who are dependent on the cafeteria throughout the week.

A building at Forest Home has been rented by the Department in which to house the help, in the belief that greater contentment and efficiency will be thereby secured.

TEACHING

The number of courses offered by the Department was as follows: first term, 8; second term, 12; Winter Course, 5.

The number of teaching hours was: First term: lectures, 9; laboratory periods, 3. Second term: lectures, 20; laboratory periods, 17. Winter Course: lectures, 13; laboratory periods, 10.

The approximate number of students in the department was as follows:

Freshmen	50
Sophomores	40
Juniors	30
Seniors	12
Students from other departments and colleges	80
Winter-course students	57
Total	269

New courses.— Three new courses were added to the departmental curriculum: Sewing, Extension, and Institution Management.

The need for development is urgent, and it is recommended that as soon as possible the Department be supported on such a financial basis as to enable it to rightly maintain its undergraduate courses and to develop graduate and research work. The growth of the Department has been greater than its possibilities of development, and if the Depart-

ment is to be maintained in a vigorous condition the two factors, growth and development, should coexist.

The success of the lodge as a practical laboratory has encouraged the hope that several houses of similar type may become a part of the property of the Department. It is recommended that this matter be given full consideration, and that as any house in the vicinity of the Home Economics Building is vacated it be considered as a possible practice house for the Department.

INVESTIGATION

No important work of investigation has been undertaken in the past year. Under present conditions investigation is impossible, since the funds at the disposal of the Department are limited and are not sufficient to maintain and develop both graduate and undergraduate work.

EXTENSION

Extension in home economics consists of Reading-Course lessons published monthly; lectures at grange meetings or before other groups, relating to rural life; organization of clubs and cooperation with them in their work; correspondence with readers, club members, and others desiring Reading-Course lessons or other information; farmers' institutes; extension schools; farm cars; and a class in extension in home economics. A three-months winter course is given for farmers' wives, and a course of lectures is held during Farmers' Week for the Home-makers' Conference.

Cornell Reading-Course for the Farm Home.— The following statement shows the number of readers and of study clubs:

Number of readers October 1, 1912	16,041
Number of readers September 30, 1913	28,446
New readers during year	12,405
Number of study clubs October 1, 1912	53
Number of study clubs September 30, 1913	66
New clubs during year	13
Requests for lessons from residents of New York State	14,915
Requests for lessons from residents of other States	980
Total number of requests	15,895

The distribution of lessons outside the State is largely confined to teachers, librarians, institute workers, and grange lecturers. Requests come from schools within the State in growing numbers. The limited number of lessons printed permits only the sending of sufficient numbers for the use of instructors and for library purposes, except in rare cases.

The following lessons were published in the Cornell Reading-Course for the Farm Home:

25. Saving strength. Emily M. Bishop and Martha Van Rensselaer.
27. Choice and care of utensils. Ida S. Harrington.
29. Cost of food. Flora Rose.
31. Household bacteriology. Martha Van Rensselaer.
33. Vegetable-gardening. Albert E. Wilkinson.
35. The flower garden. Albert E. Wilkinson.
37. Home economics at the New York State College of Agriculture. Martha Van Rensselaer.
39. The farmhouse. Helen Binkerd Young.
41. Rules for planning the family dietary. Flora Rose.
43. The box luncheon. Clara Browning.
45. Hints on choosing textiles. Bertha E. Titsworth.
47. A canning business for the farm home. Claribel Nye and Bessie Earll Austin.

Extension schools.— Extension schools in home economics were held in cooperation with the extension schools in agriculture conducted by the Department of Extension Teaching of the College. The schools lasted for five days, with one session daily. In order to secure the school a regular attendance of twenty-five or more persons throughout the week was required. A fee of seventy-five cents was charged, to pay for the expense of material used by members of the class. One food demonstration occupying two or three hours of each day, with lectures throughout the week, constituted the work of the school. Considerable equipment was furnished by local aid. A traveling equipment was sent from school to school, consisting of lesson studies, reference books, bulletins, and the necessary apparatus for demonstration purposes. A local chairman was appointed, who cooperated with the person in charge in conducting the school. Nine extension schools were conducted by the Department during the year.

Extension class.— A two-hours elective course in extension of home economics was given, open to juniors and seniors, for the purpose of teaching the principles of extension work to students interested in rural teaching. Students in the class were sent out, under supervision of the instructor, to rural schools near Ithaca to give instruction and demonstrations in domestic science. These students also visited several study clubs. Some of the students in this class are now prepared to do extension work for the Department. There were fifteen rural schools in which instruction was given by this class.

Home Economics car.— In June an arrangement was made through the Agriculturist of the Lehigh Valley Railroad, whereby the Department of Home Economics was given the use of a remodeled dining car for exhibition and demonstration purposes. The exhibit prepared consisted of a small dining room, showing principles of table-setting and choice of wall paper and curtains for a dining room. Other phases of house-planning and decoration were illustrated by plans of farmhouses, both old and remodeled, also by charts showing wall paper and furnishings suitable for various rooms.

In the subject of foods the exhibit furnished hundred-calorie portions, cans of fruit and vegetables showing various processes by which these may be preserved, and a small canning outfit similar to those used by canning clubs in the South. Economy in jelly-making processes was shown by jelly made from different extractions of currant pulp. This excited considerable interest among housekeepers because the season was that of jelly-making.

A new type of homemade fireless cooker was exhibited. The demonstration lecture on the principles and construction of this fireless cooker was received with great interest.

The exhibit included a rural-school cabinet built and equipped for the purpose of showing the feasibility of introducing a course in domestic science in the rural schools of the State. Lists and prices of equipment were furnished to teachers who were interested.

By means of clay models a lesson in sanitation was shown of a run-down, insanitary back yard contrasted with one up-to-date in every way.

Children's clothing, and work dresses for women, approved as hygienic and labor-saving, were exhibited. In order that this clothing might be duplicated, details for making were included in the exhibit.

The car was exhibited for nearly three weeks, the following places being reached: Ovid, Stanley, Interlaken, Trumansburg, Ithaca, Spencer, Sayre, Milan (Pennsylvania), Cortland, New Woodstock, and Cazenovia. The average number of persons who visited the car was about fifty. Two members of the Department were with the car, assisted by members of the class in extension. The exhibits in the car were explained and demonstration lectures were given.

Lectures.— A member of the staff employed as an extension worker was given a three-months leave of absence in order that she might assist in the work at farmers' institutes under the direction of the State Department of Agriculture. As opportunity was offered, other members of the staff gave lectures throughout the year at granges, extension schools, Cornell study clubs, and meetings held in the interests of agriculture and home economics. The number of meetings attended during the year

was one hundred and twenty-five; the number of lectures given was one hundred and ninety-three.

Recommendations.— As early as possible it is hoped that the appropriation for extension in Home Economics may be sufficient to include teaching, in rural communities, the practical arts suited to rural life. Such teaching should have special reference to the farm girls who may thereby find remunerative labor at home, thus encouraging them to remain and contribute their share toward rural progress both in the community and in the home.

FLORA ROSE,
MARTHA VAN RENSSELAER,
Professors of Home Economics.

DEPARTMENT OF METEOROLOGY

TEACHING

During the past year 219 students received instruction in meteorology and climatology in the courses offered by this Department. The numbers registered in the several courses were as follows: Regular course in Meteorology and Climatology, 170; Summer School, 46; Graduate School, 3.

INVESTIGATION

Two lines of investigation have been undertaken during the past year, namely, the influence of the smaller bodies of water in the State on the temperature of adjacent regions, and a correlation study of the relation of rainfall to the yield of hay in this State. These investigations are not yet completed.

EXTENSION

Extension work by this Department has been limited to filling a number of engagements made through the Department of Extension Teaching. As in past years, the Department has collected climatological data from about one hundred and twenty-five cooperative stations in the State. These data have been published in tabular form and discussed in the Monthly Weather Review.

WILFORD M. WILSON,
Professor of Meteorology.

EXTENSION DEPARTMENT

TEACHING

The three courses in extension teaching that were given during the past year aimed to bring the students into closer touch with the agricultural affairs in their communities, through study of the principles of organization and through practice in writing on and in presenting country-life subjects. Parliamentary practice was given in connection with Course 2. The registration in these three courses was much greater than that of the previous year; there were 107 students registered in course 1, 62 in course 2, and 39 in course 14 (in the Winter Courses). Each student received individual attention each week, through a personal appointment covering thirty minutes. This individual work is considered a strong part of the courses. It formed the equivalent of eleven laboratory periods of three hours each for course 1, six laboratory periods of three hours each for course 2, and three laboratory periods of three hours each for course 14.

A larger number of students competed for the Eastman Stage in public speaking than was the case in the previous year. Over fifty entered the first competition. The winter-course stage received attention from the members of the staff, as well as the winter-course debate for the Morrison cup.

EXTENSION

The extension activities of the College arranged through the Extension Department followed mainly the lines of the preceding year. More attention was given to lecture courses and other continuous work. The extension schools were increased in number and have now come to be recognized as a strong factor in the extension work. Requests for lectures by members of the college staff before county and subordinate granges, fairs, agricultural and horticultural clubs, farmers' and teachers' institutes, dairymen's and poultrymen's associations, schools, churches, Young Men's Christian Associations, and farmers' picnics were filled whenever possible. In addition to the activities arranged by the Extension Department, many others were conducted directly by the other departments concerned. Notice of such activities should appear in the departmental reports.

Lectures and meetings

Directly on the funds of the Extension Department there were given 304 lectures with an attendance of 26,756 persons, as is shown

below, and 40 lectures in addition the attendance at which was not reported:

County	Meetings	Attendance	Number of meetings with attendance not reported
Albany	7	1,520	1
Allegany	1	200	....
Broome	5	825	3
Cattaraugus	4	235	....
Cayuga	29	1,902	....
Chautauqua	7	368	....
Chemung	17	1,872	....
Chenango	....	....	1
Clinton	....	....	4
Cortland	4	251	2
Dutchess	2	500	....
Erie	13	591	1
Essex	....	....	5
Franklin	1	60	2
Fulton	1	62	....
Genesee	2	220	....
Greene	1	500	....
Herkimer	5	168	....
Jefferson	1	25	....
Kings	4	400	....
Livingston	4	275	....
Madison	4	675	....
Monroe	16	2,327	....
Montgomery	1	45	....
Nassau	3	86	....
Niagara	4	785	4
Oneida	21	1,965	....
Onondaga	4	290	....
Ontario	9	1,020	1
Orange	16	1,106	....
Orleans	3	355	2
Oswego	2	269	1
Otsego	5	164	1
Queens	3	142	1
Rensselaer	1	50	....
Rockland	3	101	....
St. Lawrence	3	645	....
Saratoga	1	125	....
Schenectady	....	....	3
Schoharie	9	365	3
Schuyler	7	330	....
Seneca	8	727	....
Steuben	9	820	....
Suffolk	1	130	....
Sullivan	13	498	....
Tioga	1	40	....
Tompkins	25	1,741	2
Ulster	5	250	....
Warren	1	20	....
Washington	....	....	2
Wayne	10	840	1
Wyoming	1	60	....
Yates	7	811	....
Total	304	26,756	40

The following meetings were arranged during the year; those marked with an asterisk were arranged through the Department of Poultry Husbandry:

Town	Date	Nature of meeting	Speakers from College
Danby	October 1	Lecture	W. G. Krum
Walton	October 2	Conference	Professor Tuck
Painted Post	October 4	Lecture	Miss McCloskey
New Woodstock	October 5	Lecture	Mrs. Harrington
Jacksonville*	October 8	Lecture	Mr. Krum
Alpine	October 8	Lecture	Professor Minns
Brockton*	October 9	Lecture	Mr. Krum
Willow Creek*	October 10	Lecture	Mr. Krum E. W. Benjamin
Elmira	October 11	Lecture	Mr. Krum
Ithaca	October 11	Rural teachers' conference	
Stittville	October 15	Farm visit	Professor Minns
Mohawk	October 16	Farm visit	Professor Minns
Herkimer	October 16	Lecture	Mr. Krum
Poland	October 16	Conference	Professor Tuck
Penn Yan	October 17	Lecture	R. L. Edwards
Rome*	October 18	Lecture	Mr. Krum
Ithaca	October 19	Meeting of county agents	
Poughkeepsie	October 19	Lecture	Professor Montgomery
Herkimer county	October 22–25	Lectures	Mr. Krum
Schuyler	October 22	Lecture	Mr. Krum
Jordanville	October 23	Lecture	Mr. Krum
Warsaw	October 24	Conference	Professor Tuck
Russia	October 24	Lecture	Mr. Krum
Sinclairville	October 25	Conference	A. C. King
Rome	October 25	Lecture	H. B. Winters
North Ridge	October 26	Lecture	A. C. King
Cazenovia*	October 28	Lecture	R. P. Trask
Hancock	November 1	Lecture	Professor Cavanaugh
North Bangor	November 1	Conference	Professor Tuck
Bath	November 1	Lecture	Professor Ross
Corning*	November 5	Lecture	Mr. Krum
Orrs Mills*	November 7	Lecture	Mr. Krum
Auburn*	November 7	Lecture	Mr. Krum
Elmira	November 8–9	Lectures	Mr. Krum
Cornwall*	November 8	Lecture	Mr. Krum
Newark	November 8	Lecture	Mrs. Harrington
Newark Valley	November 8	Lecture	Dr. W. M. Wilson
Jacksonville	November 9	Lecture	Professor Barrus
Meadowdale	November 9	Lecture	Mr. Krum
Atlanta, Georgia	Nov. 11–13	American Association of Farmers Institute Workers	
Mexico	November 11	Lecture	Professor Mann
Mayville	November 11	Lecture	Professor Tuck
Middletown*	Nov. 12–15	Lectures	L. M. Hurd
Middleport	November 12	Lecture	Professor Tuck
Warsaw	November 12	Farm visit	Professor Minns
Gaines	November 14	Lecture	Professor Tuck
Ovid	November 15	Lecture	Professor Cross
New York City*	Nov. 18–20	Lectures	Mr. Krum
Tallman*	November 18	Lecture	Mr. Krum
Spring Valley*	November 19	Lecture	Mr. Krum
New York City*	November 20	Lecture	Mr. Hurd
New City*	November 20	Lecture	Mr. Krum
Yonkers*	November 21	Lecture	Mr. Hurd
McGraw	November 21	Lecture	Professor Mann
Moravia	November 22	Lecture	Mrs. Harrington
Rome*	November 23	Lecture	Mr. Krum
Geneva	Nov. 25–27	Normal Institute	Institute workers
Oswego	November 27	Conference	Professor Tuck
Newark	November 29	Lecture	Professor Fippin
Cuyler	November 30	Lecture	Professor Savage
North Rose	December 2–7	Extension school	L. S. Tenny Mr. Krum Professor Fippin A. E. Wilkinson A. C. King
New York City*	December 3–7	Empire Poultry Association	L. M. Hurd
South Framingham, Massachusetts	December 4	Lecture	Professor Rice
Hepburnville, Pennsylvania	December 6	Lecture	Professor Tuck
Walton	December 9–14	Extension school	Professor Minns Mr. Hurd Professor Hopper W. L. Markham

Town	Date	Nature of meeting	Speakers from College
Perry	December 9–14	Extension school	Professor Fippin
			R. P. McPherson
			Mr. Markham
			T. H. King
Derby	December 9	Lecture	B. B. Robb
Rochester	Dec. 11–13	New York State Horticultural Society	
Verona	December 11	Lecture	Royal Gilkey
Elmira*	December 13	Lecture	Mr. Krum
Monticello	December 13	Lecture	Professor Tuck
Oswego	December 14	Fruit Growers' Association	Professor Reddick
			Professor Herrick
Canandaigua*	December 16	Lecture	Mr. Krum
Salamanca	Dec. 16–31	Extension school	Mr. McPherson
			Professor Hopper
			Mr. Markham
			Professor Fippin
Olean*	Dec. 17–21	Poultry show	Mr. Trask
Cohoes	December 18	Lecture	Professor Savage
Geneva*	December 19	Lecture	Professor Rice
Marcellus	December 19	Lecture	Professor Tuck
Newark	December 20	Lecture	H. B. Knapp
Breakabeen	December 20	Lecture	Professor Wing
East Bloomfield	December 20	Lecture	Professor Tuck
Union Springs*	December 27	Lecture	Mr. Hurd
Gilboa	Dec. 27–28	Lectures	Mr. Hurd
State College, Pennsylvania*	December 28	Lecture	Professor Rice
Mexico	Dec. 30–Jan. 4	Extension school	Professor Minns
			Harry King
			Professor Hopper
			Mr. Markham
			Mr. Hurd
Oneonta	Dec. 30–Jan. 4	Extension school	Mr. McPherson
			Professor Hopper
			Mr. Markham
			Mr. Trask
Owego	January 2	Lecture	Professor Tuck
Elmira	January 3	Conference	Professor Tuck
Watkins	January 3	Conference	Professor Tuck
Romulus	January 4	Lecture	Professor Tuck
Auburn	January 6	Conference	Professor Tuck
Poland	January 6–11	Extension school	Professor Fippin
			Mr. Markham
			Professor Myers
			Professor Hopper
			Professor Barrus
Buffalo	January 7	Lecture	Mr. Wilkinson
Venice Center	January 7	Lecture	Professor Tuck
Penn Yan	January 7	Conference	Professor Tuck
Binghamton	January 7–10	Lectures	Professor Tuck
Albany	January 9	Lecture	Mr. Trask
Auburn	January 9	Lecture	Professor Montgomery
Elmira*	January 10	Lecture	Mr. Krum
Rochester*	January 10	Lecture	Professor Rice
Silver Creek	January 11	Lecture	E. L. Markell
Rushville	January 11	Lecture	Professor Ross
Sinclairville	January 13–18	Extension school	A. C. King
			Professor Hopper
			Mr. Hurd
			Professor Fippin
Romulus	January 15	Conference	Professor Tuck
Forestville	January 15	Lecture	A. C. King
Gouverneur	January 17	Lecture	Professor Tuck
Utica	January 17	Lecture	Professor Love
Waddington	January 20	Farmers' Institute	Professor Tuck
Atwater	January 20	Lecture	Professor Van Rensselaer
Wolcott	January 20	Lecture	Professor Fippin
Lowville	January 20–25	Extension school	Professor Minns
			Mr. Trask
			Mr. Knapp
			Professor Hopper
North Bangor	January 20–25	Extension school	A. C. King
			Professor Hopper
			Mr. Markham
			Professor Barrus
Massena	January 21	Farmers' Institute	Professor Tuck
Winthrop	January 22–23	Farmers' Institute	Professor Tuck
Morrisville*	January 22	Lecture	Mr. Benjamin
Lawrenceville	January 23	Farmers' Institute	Professor Tuck

Town	Date	Nature of meeting	Speakers from College
Albany*	January 23	Lecture	Mr. Benjamin
Greigsville	January 23	Lecture	Professor Cavanaugh
Bombay	January 24–25	Farmers' Institute	Professor Tuck
Bellona	January 24	Lecture	Professor Cross
Batavia*	January 25	Lecture	Professor Rogers
Newfane	January 25	Lecture	Professor Herrick
Southampton	Jan. 27–Feb. 2	Extension school	Professor Fippin Mr. Hurd Mr. Wilkinson Mr. Markham Professor Barrus
Kinderhook	Jan. 27–Feb. 2	Extension school	Professor Hopper Mr. Krum Professor Stone Mr. Tenny
Nassau	January 27	Lecture	Mr. Krum
Enfield	January 28	Lecture	Professor Savage
Canton	January 29	Lecture	Professor Myers
Breakabeen	January 31	Lecture	Mr. Knapp
Far Rockaway	January 31	Lecture	J. Van Wagenen
Ravena	February 3–8	Extension school	Professor Hopper Professor Myers Professor Cross
Le Roy	February 3–8	Extension school	A. C. King Mr. Krum Mr. Markham Professor Barrus
Clayton*	February 4–6	Lectures	Mr. Hurd
Groton	February 4	Lecture	Professor Davis
Cohoes	February 5	Lecture	Professor Cross
Albany	February 6	Lecture	Mr. Trask
Wyoming	February 6	Lecture	Professor Spring
Townsendville	February 6	Lecture	Professor Fippin
Bellona	February 7	Lecture	Professor Fippin
Portland	February 15	Lecture	Mr. Wilkinson
Newfield	February 15	Lecture	E. D. Wallenbeck
Gouverneur*	February 17	Lecture	Mr. Krum
Lockport	February 17–22	Extension school	A. C. King Professor Fippin Professor Barrus L. F. Strickland Mr. Hurd
Alden	February 17–22	Extension school	Professor Minns Professor Hopper Mr. Trask
Albany	February 17	Lecture	Mr. Krum
Syracuse	February 21	Lecture	Professor Tuck
Marlborough	February 21	Lecture	Professor Cavanaugh
Geneseo	Feb. 24–Mar. 1	Extension school	Professor Hopper Mr. Hurd S. Fraser Professor Warren Doctor Dunham
Mountainville	Feb. 24–Mar. 1	Extension school	A. C. King Mr. Krum Mr. Markham F. S. Hayden
Palatine Bridge	February 26	Lecture	Mr. Wilkinson
Waterburg	February 27	Lecture	Professor Tuck
Watkins	February 27	Lecture	Professor Stone
Bellona	February 28	Lecture	Professor Wing
Port Byron	February 28	Lecture	Mr. Knapp
Ticonderoga	March 3–8	Extension school	Mr. Krum Mr. Markham Mr. Knapp Professor Cross
East Bloomfield	March 3–8	Extension school	A. C. King Professor Fippin Professor Barrus C. R. White Professor Stone
Albany	March 6	Lecture	Professor Rogers
Alfred*	March 6	Lecture	Mr. Trask
Walworth	March 7	Lecture	Professor Fippin
Dryden*	March 8	Lecture	Mr. Benjamin
Barker	March 8	Lecture	Director Bailey
Watertown	March 10–15	Extension school	Professor Myers Mr. Markham Professor Wing F. E. Robertson Professor Stone

Town	Date	Nature of meeting	Speakers from College
Holley	March 10–15	Extension school	Professor Fippin T. H. King, Jr. Professor Barrus Mr. Wilkinson
Derby	March 10	Lecture	Professor Bentley
Cato	March 10	Lecture	Mr. Krum
Meridian	March 10	Lecture	Mr. Krum
Bellona*	March 11	Lecture	Mr. Krum
Fleming	March 12	Lecture	Professor Cavanaugh
Gates	March 13	Lecture	Professor Fippin
Ripley	March 13	Lecture	Professor Tuck
Cheshire	March 14	Lecture	Professor Fippin
Johnstown	March 17–22	Extension school	Mr. Krum H. L. Ayres Professor Stone Professor Barrus
Rochester	March 17	Lecture	Professor Tuck
Five Corners	March 17	Lecture	Mr. Krum
Atwater	March 17	Lecture	Mr. Knapp
Gloversville*	March 18	Lecture	Mr. Krum
Alfred	March 18	Lecture	Professor Tuck
Buffalo	March 18	Lecture	Mr. Wilkinson
Ossining*	March 19	Lecture	Mr. Krum
Albany	March 20	Lecture	Mr. Krum
Ithaca	March 20	Lecture at College	M. G. Kains
Merrifield	March 20	Lecture	Professor Tuck
Jamaica	March 20	Lecture	Mr. Wilkinson
Fayetteville	March 21	Lecture	Professor Rice
Greigsville	March 21	Lecture	T. Eaton
Jamaica	March 21	Lecture	Mr. Wilkinson
Honeoye	March 22	Lecture	Mr. Krum
Honeoye	March 22	Lecture	Professor Bentley
Jamaica	March 22	Lecture	Mr. Wilkinson
Jordan	March 25	Lecture	Professor Rogers
Buffalo	March 25	Lecture	Mr. Wilkinson
Aurora	March 28	Lecture	Professor Love
Lyons	March 29	Lecture	Miss Knowlton
Rose	March 29	Lecture	Professor Davis
Cortland	March 29	Lecture	F. E. Rogers
Buffalo	April 1	Lecture	Mr. Wilkinson
Breakabeen	April 3	Lecture	Professor Cross
Honeoye	April 3	Lecture	Mr. Krum
Syracuse	April 3	Lecture	Professor Bentley
Red Creek	April 4	Lecture	Professor Wing
Brooklyn	April 4	Lecture	Professor Wilson
Cochecton Center	April 5	Lecture	Professor Cross
Sherman	April 5	Lecture	Mr. Krum
Holley*	April 7	Lecture	Professor Rice
Aurora	April 7	Lecture	Professor Van Rensselaer
Buffalo	April 8	Lecture	Mr. Wilkinson
Odessa	April 10	Lecture	Professor Wing
Brooklyn	April 11	Lecture	Professor Wilson
Buffalo	April 15	Lecture	Mr. Wilkinson
Frankfort	April 15	Lecture	Professor Stone
Merrifield	April 17	Lecture	Miss Knowlton
Brooklyn	April 18	Lecture	Professor Wilson
North Wolcott	April 19	Lecture	Mr. Knapp
Waterloo	April 19	Lecture	Miss Knowlton
Buffalo	April 22	Lecture	Mr. Wilkinson
Brooklyn	April 25	Lecture	Professor Wilson
Fleming	April 25	Lecture	Miss Knowlton
Frewsburg	April 25	Lecture	H. B. Rogers
Honeoye	May 3	Lecture	Professor Fippin
Ovid	May 7	Lecture	Mr. Wilkinson
Rock Stream	May 10	Lecture	Professor Cavanaugh
Derby	May 13	Lecture	Professor Cavanaugh
Sherwood	May 15	Lecture	Professor Bentley
Mecklenburg	May 16	Lecture	Professor Mann
Little Falls	May 31	Lecture	Miss Knowlton
Syracuse*	June 2	Lecture	Professor Rice
Ovid	June 4	Lecture	Professor Stone
West Niles	June 5	Lecture	Professor Stone
Ensenore	June 6	Lecture	Mr. Benjamin
Dresserville	June 6	Lecture	Professor Stone
Trumansburg	June 7	Lecture	Professor Van Rensselaer
Interlaken	June 7	Lecture	Professor Barrus
Newfield	June 7	Lectures	Mr. Wilkinson Professor Troy Professor Savage

Town	Date	Nature of meeting	Speakers from College
Derby	June 9	Lecture	R. H. Wheeler
Cortland	June 11	Farm visit	Mr. Wheeler Professor Stone Professor Savage
Gates	June 12	Lecture	Miss Genung
Newfane	June 14	Lecture	Professor Pippin
Sennett	June 17	Lecture	Professor Barrus
Waterville	June 23–27	Extension school	Department of Home Economics
Ithaca	June 24	Grange Day at College of Agriculture	
New Berlin	June 25	Lecture	Professor Pippin
Ithaca	June 26	Annual visit to College of Stanley's boys from Elmira	
Ithaca	June 26	Picnic from Barton, New York, at College	
Ithaca	June 27	School Day at College of Agriculture	
Eastport	June 28	Lecture	Professor Rice
East Groveland	July 2	Lecture	Professor Pippin
Watertown	July 2	Lecture	Professor Savage
East Groveland	July 3	Lecture	Professor Stone
Bolton Landing	July 26	Lecture	Professor Savage
Odessa	July 26	Lecture	Miss Genung
Conklin Center	August 7	Lecture	Professor Ross
Olcott	August 8–9	Fruit growers' meeting	Mr. Wheeler
Weedsport	August 8	Lecture	Professor Stone
Dresserville	August 12	Lecture	Professor Barrus
Four Town	August 13	Lecture	Professor Barrus
Scipio Center	August 14	Lecture	Professor Barrus
Port Byron	August 14	Lecture	Professor Stone
Cortland	August 19	Conference	Mr. Wheeler
Ballston Lake	August 21	Lecture	Professor Cavanaugh
Richford	August 22	Lecture	Professor Ross
Springport	August 25	Lecture	Mr. Wilkinson
Willets	September 25	Lecture	Professor Van Rensselaer

Farmers' Week

The registered attendance at the Sixth Annual Farmers' Week, held February 10 to 15, was 2409. It was impossible to register all the visitors, but it was estimated that 3100 were in attendance during the week. There were offered two hundred and eighty-four lectures, ten demonstrations, ten contests and competitions, and sixteen laboratory courses. Seventeen associations held their meetings during the week. A summarized statement of Farmers' Week follows:

	Lectures	Demonstrations	Contests and competitions	Laboratory courses
Monday	32	....	1	4
Tuesday	59	2	3	4
Wednesday	67	3	1	0
Thursday	61	3	2	4
Friday	52	2	3	4
Saturday	13	....	....	....
Total	284	10	10	16

Number of conventions and conferences........................ 17

- Drainage convention
- Dairy Students' Association
- Federation of Floral Clubs conference
- Home-makers' conference
- Plant-breeders' Association
- Poultry Association conference
- Rural Engineering conference
- Rural Church conference
- Rural School Education
- Students' Association conference
- Vegetable-growers' convention
- Experimenters' League conference
- Rural Cooperative Credit conference
- State Institutions Farm Managers' conference
- Agricultural Speakers' conference
- Boys' conference
- Fruit-growers' conference

Number of exhibitions by departments........................ 16

- Animal Husbandry
- Books
- Dairy
- Entomology
- Farm Mechanics
- Forestry
- Home Economics
- Horticulture
- Plant-breeding
- Plant Pathology
- Plant Physiology
- Potato show
- Poultry Husbandry
- Rural School Education
- Soil Technology
- Weather Bureau

Number of speaking contests among students.................. 3

- Eastman Stage
  - C. W. Whitney, winner of first prize
  - M. A. Gonzalez, winner of second prize
  - W. H. Bronson
  - P. R. Guldin
  - F. E. Geldenhuys
  - J. H. Munn
- Winter-course Stage
  - B. T. Roberts, Horticultural Club, winner
  - H. W. Stewart, General Agricultural Club
  - F. M. LeWeck, Poultry Club

Morrison Debate (Winter Course)
Home Economics, winner
Mrs. J. D. Foote
Miss Louise M. Orchard
Mrs. M. C. Smith
Poultry
N. L. Harris
R. Marion
L. C. Soule

Number of cooperating lecturers outside the College	55
Total registration for the week	2409
Estimated attendance	3100

In addition to the sixteen laboratory courses listed above, which were conducted by the Department of Poultry Husbandry, the Department of Home Economics conducted an extension school in laboratory practice from Tuesday to Friday inclusive.

Three shows were conducted by the Department of Poultry Husbandry: a blue-ribbon poultry show, a dressed-poultry show, and an egg show.

Fairs

The demand for educational exhibits at fairs was greater than for the preceding year. Sixteen departments were represented at the State Fair. Educational exhibits were sent to twenty-nine county fairs, the transportation expenses being shared, dollar for dollar, between the local society and the College. It was estimated that 340,000 persons were brought in touch with the College through these educational exhibits. Below is given a summary of the State Fair and the county fairs:

Town	County	Date	Departments exhibiting
Newark Valley	Tioga	Aug. 5–7	Plant Pathology
Fulton	Oswego	Aug. 12–15	Plant Pathology
Cortland	Cortland	Aug. 19–22	Dairy, Agricultural Chemistry
Wellsville	Allegany	Aug. 19–22	Poultry, Animal Husbandry
Warsaw	Wyoming	Aug. 19–22	Entomology, Plant Pathology
Hamburg	Erie	Aug. 26–29	Entomology
Moravia	Cayuga	Aug. 26–29	Poultry, Soils
Middletown	Orange	Aug. 26–29	Agricultural Chemistry
Hudson Falls	Washington	Aug. 26–29	Pomology
Trumansburg	Tompkins	Aug. 26–29	Animal Husbandry (Feeds)
Olean	Cattaraugus	Sept. 1–5	Entomology, Dairy
Dryden	Tompkins	Sept. 2–5	Agricultural Chemistry, Animal Husbandry
Dunkirk	Chautauqua	Sept. 2–5	Farm Crops
Warrensburg	Warren	Sept. 2–5	Pomology
Watertown	Jefferson	Sept. 2–5	Poultry
Rome	Oneida	Sept. 2–5	Soils
Brockport	Monroe	Sept. 3–6	Poultry
Plattsburg	Clinton	Sept. 8–12	Poultry

Town	County	Date	Departments exhibiting
Syracuse	(State Fair)	Sept. 8–13	Poultry, Dairy, Animal Husbandry, Forestry, Pomology, Horticulture, Entomology, Plant-breeding, Plant Pathology, Farm Management, Farm Crops, Plant Physiology, Soil Technology, Agricultural Chemistry, Rural Engineering, Extension
Elmira	Chemung	Sept. 15–19	Farm Crops, Pomology
Ithaca	Tompkins	Sept. 16–19	Poultry, Animal Husbandry, Vegetable-gardening
Riverhead	Suffolk	Sept. 16–19	Entomology, Plant Pathology
Malone	Franklin	Sept. 16–19	Agricultural Chemistry
Cazenovia	Madison	Sept. 17	General, Extension
Batavia	Genesee	Sept. 17–20	Dairy, Veterinary, Soils, Drainage
Lockport	Niagara	Sept. 22–27	Soils
Bath	Steuben	Sept. 24–26	A representative as judge
Perry	Wyoming	Sept. 24–26	Poultry
Binghamton	Broome	Sept. 30–Oct. 3	Dairy
Poughkeepsie	Dutchess	Sept. 29–Oct. 3	Vegetable-gardening, Soils

Extension schools

During the winter of 1912–1913 twenty-four extension schools were held in twenty-three counties, with a total registration of 1198 persons. These schools were arranged for at the request of communities, and only when a registration of forty was assured in advance. The following is a summarized statement of the extension schools:

Town	County	Date	Registration			Expenses	Tuition
			Men	Women	Total		
North Rose (cancelled)	Wayne	Dec. 2–7	......	......	......	$41.81	....
Perry	Wyoming	Dec. 9–14	45	26	71	137.57	$87.00
Walton	Delaware	Dec. 9–14	20	11	31	121.13	26.50
Salamanca	Cattaraugus	Dec. 16–21	11	7	18	74.81	15.75
Mexico	Oswego	Dec. 30–Jan. 4	43	27	70	143.27	84.75
Oneonta	Otsego	Dec. 30–Jan. 4	33	......	33	121.68	49.50
Poland	Herkimer	Jan. 6–11	23	22	45	154.00	47.00
Sinclairville	Chautauqua	Jan. 13–18	50	......	50	115.12	75.00
Lowville	Lewis	Jan. 20–25	22	23	45	137.47	50.00
North Bangor	Franklin	Jan. 20–25	31	......	31	93.25	46.50
Kinderhook	Columbia	Jan. 27–Feb. 1	41	51	92	102.13	105.75
Southampton	Suffolk	Jan. 27–Feb. 1	26	36	62	209.88	64.00
Le Roy	Genesee	Feb. 3–8	28	......	28	101.09	42.00
Ravena	Albany	Feb. 3–8	49	......	49	90.31	73.50
Alden	Erie	Feb. 17–22	32	3	35	60.16	52.50
Lockport	Niagara	Feb. 17–22	84	......	84	153.21	126.00
Mountainville	Orange	Feb. 24–Mar. 1	28	6	34	103.32	51.00
Geneseo	Livingston	Feb. 24–Mar. 1	36	5	41	55.57	60.00
East Bloomfield	Ontario	Mar. 3–8	51	31	82	101.98	104.70
Ticonderoga	Essex	Mar. 3–8	30	4	34	127.47	51.00
Watertown	Jefferson	Mar. 10–15	23	......	23	91.42	34.50
Holley	Orleans	Mar. 10–15	67	......	67	46.56	100.50
Johnstown	Fulton	Mar. 17–22	46	3	49	74.05	73.50
Hannibal	Oswego	Mar. 24–29	33	22	55	59.54	66.00
Lincolndale	Westchester	Mar. 24–29	69	......	69	93.44	12.00
Total	....	....	921	277	1,198	$2,610.24	$1,498.95
Average	....	....	38.4	18.5	49.9	104.41	62.46

Tuition: Domestic science, 75 cents per student for the week; general extension school, $1.50 per student for the week.

The staff for each school consisted of an average of three persons throughout the week.

Farm trains

During the past fiscal year, three farm trains were operated over the New York Central & Hudson River Railroad, in addition to one operated by the Department of Home Economics in cooperation with the Lehigh Valley Railroad. Brief statements of each farm train are here given:

Poultry Husbandry.— This train was run on the Auburn and Batavia branches of the New York Central, October 28 to 31, 1912. The work was in charge of L. M. Hurd and W. G. Krum.

Two coaches were used: one was equipped for demonstration purposes; the other was equipped for lectures and discussions on the more important phases of poultry husbandry, including feeding for egg production and for market broilers, grading of eggs, construction of poultry houses, principles of breeding, and other items related to the raising of poultry for profit. The demonstration car contained exhibits of poultry appliances, including egg and poultry carriers, picking boxes, feeding hoppers, and trap nests; also photographic enlargements and charts showing methods of rearing chickens and of caring for fowls, and results of experiments with poultry. The schedule was as follows:

Station	Date	Time of meeting	Attendance
Syracuse	October 28	2.30 and 7.30 p. m.	900
Auburn	October 29	9 a. m. to 12 m.	200
Seneca Falls	October 29	2.30 to 5.30 p. m.	175
Geneva	October 29	7.30 to 9.30 p. m.	400
Canandaigua	October 30	10.30 a. m. to 12 m.	150
Honeoye Falls	October 30	7 to 9.30 p. m.	55
Le Roy	October 31	8.30 a. m. to 1 p. m.	120
Batavia	October 31	1.30 to 5 p. m.	100
Total attendance	....	....	2,100

Vegetable-growing.— This train was run on the West Shore Division of the New York Central, March 31 to April 5, 1913, under the charge of Professor A. C. Beal, A. E. Wilkinson, and Paul Work.

Two coaches were used, one of which was equipped for demonstration purposes and the other for lectures and discussions. The demonstration car contained exhibits of packages used in marketing, material for hotbed

construction, tools for garden use, a Skinner irrigation model, a sterilizing model, collections of seeds, flowering plants, and preserved vegetables, a greenhouse model, and seed-testers. In the lecture coach discussions were held on the planting of seeds, transplanting, the use of market baskets and boxes, the construction of the greenhouse, the management of the greenhouse, the construction and management of hotbeds, planning the vegetable garden, growing early plants, irrigation and harvesting, packing and marketing. The schedule was as follows:

Station	Date	Time of meeting	Attendance
Newburg	March 31	2 to 9 p. m.	180
Kingston	April 1	2 to 9 p. m.	140
Catskill	April 2	2 to 5 p. m.	70
Coxsackie	April 2	7 to 9 p. m.	64
Albany	April 3	2 to 9 p. m.	270
Schenectady	April 4	2 to 9 p. m.	375
Troy	April 5	2 to 9 p. m.	269
Total attendance			1,368

Soils, dairying, and fruit-growing.— This car, in charge of Professors E. O. Fippin and E. S. Savage, was operated over the Harlem Division of the New York Central, November 12 to 14, 1912.

Two coaches were equipped, one for demonstration purposes and the other for lectures and discussions. The demonstration car contained exhibits of commercial fertilizers, forms of lime, drain tile, apparatus showing the effect of mulches, dairy feeds, dairy appliances, and insect pests. In the lecture coach discussions were held on the important phases of dairying, soil management, soil fertility, and fruit production. The schedule was as follows:

Station	Date	Time of meeting	Attendance
Chatham	November 12	10 a. m. to 12 m.	210
Craryville	November 12	1.30 to 3.30 p. m.	40
Copake	November 12	7 to 9 p. m.	75
Millerton	November 13	9 a. m. to 12 m.	80
Amenia	November 13	2.30 to 5 p. m.	65
Dover Plains	November 13	7.45 p. m.	180
Wingdale	November 14	8 to 9.30 a. m.	42
Pawling	November 14	9.45 a. m. to 12 m.	70
Patterson	November 14	1.30 to 4.30 p. m.	65
Total attendance			827

Summary

Summarizing the events as given above, the College has reached approximately the following number of persons through the means described:

Single extension lectures and lecture courses	26,756
Farmers' Week	3,100
Fairs	340,000
Extension schools	1,198
Farm trains	4,295
	375,349

Experimenters' League

Below is given a report of the work done by the Experimenters' League during the past year. The membership list has been revised, and personal correspondence has been taken up with each member. Many who were conducting definite experiments were visited by members of the college staff.

Membership by counties:

Albany	11
Allegany	9
Broome	16
Cattaraugus	10
Cayuga	29
Chautauqua	32
Chemung	8
Chenango	20
Clinton	4
Columbia	14
Cortland	18
Delaware	13
Dutchess	14
Erie	25
Essex	12
Franklin	10
Fulton	4
Genesee	35
Greene	4
Herkimer	9
Jefferson	13
Kings	10
Lewis	7
Livingston	10
Madison	14
Monroe	30
Montgomery	7
Nassau	1
New York	14
Niagara	18
Oneida	33
Onondaga	34
Ontario	36
Orange	14
Orleans	17
Oswego	26
Otsego	16
Queens	3
Rensselaer	12
Richmond	5
Rockland	4
St. Lawrence	31
Saratoga	13
Schenectady	10
Schoharie	9
Schuyler	10
Seneca	21
Steuben	16
Suffolk	12
Sullivan	1
Tioga	11
Tompkins	143
Ulster	15
Washington	4
Wayne	15
Westchester	10
Wyoming	13
Yates	8

Total membership enrolled, 963.

Experiments undertaken by members of the league:

Alfalfa	19	Cauliflower	1	Vetch	1
Clean milk	1	Grapes	1	Celery	1
Corn	11	Sugar beets	2	Strawberries	1
Fertilizers	7	Nuts	1	Bees	1
Pasture	1	Onions	2	Flowers	1
Alsike clover	2	Gardening	1	Green manure	1
Ensilage	1	Tomatoes	3	Oats	7
Wheat	1	Inoculation of garden peas	1	Potatoes	16
Tree-setting	1	Comparative variety tests	1	Poultry	6
General farming	1	Cowpeas and spring rye	1	Soy beans	6
Seed in grass	1			Spraying	5
Beans	2				
Fruit	2				

Total, 110.

County agents

Since the last annual report, each one of seven counties has appointed a representative to act as its agent. These representatives assist in arranging for the various extension enterprises for the county, by giving advice to the local people and counsel to the College. The county agent affords a means of bringing the College into closer relationship with the people.

The following is a list of the county agents to date:

Cattaraugus	F. N. Godfrey, Olean
Cayuga	Charles Fitts, Moravia
Chautauqua	S. J. Lowell, Fredonia
Chemung	Oscar Kahler, Elmira
Clinton	H. L. Scribner, Plattsburg
Cortland	Miles Peck, Cortland
Genesee	A. H. Call, Batavia
Herkimer	H. A. Crofoot, Little Falls
Jefferson	F. C. Overton, Adams
Orange	Albert Manning, Otisville
Oswego	M. J. Upton, Sandy Creek
Otsego	C. H. Baker, Oneonta
Schuyler	Harry S. Gabriel, Rock Stream
Seneca	L. C. Bradley, Interlaken
Suffolk	S. C. Hedges, East Hampton
Tioga	L. C. Burt, Catatonk
Yates	G. L. Wheeler, Penn Yan

CORRESPONDENCE

The number of letters received during the year was 30,467; the number sent out was 27,212.

CORNELL READING-COURSE FOR THE FARM

There has been a large increase in the demand for Reading-Course Lessons for the Farm. During the past year 22,533 of these lessons were sent on request, as compared with 16,704 during the previous year. An increased interest has also been shown in the discussion papers. During the past year 11,156 discussion papers were returned, as compared with 6662 for the previous year — a gain of 67 per cent. The following statement shows the series of lessons, the number of lessons available in each series, new readers by series, discussion papers returned, enrollment, and number of study clubs:

Series	Number of lessons	New readers by series	Discussion papers returned
The soil	2	378	945
Poultry	3	900	2,087
Rural engineering	1	103	239
Farm forestry	3	128	709
The horse	2	153	466
Dairying	2	193	899
Fruit-growing	4	456	1,629
Farm crops	2	462	1,756
Stock-feeding	1	216	815
Vegetable-gardening	2	250	1,017
Plant-breeding	2	47	594
Total	24	*3,286	11,156

New readers	2,042
Old readers renewed	625
Readers continued from previous year	1,217
Total on mailing list	3,884
Cornell study clubs	13

*Since many readers enroll for more than one series, the total new readers by series is greater than the number of new readers given below.

PUBLICITY

A selected list of two hundred and fifty newspapers in the State has been prepared, comprising those that have requested special press notices from the College. During the year seventy-two special notices of meetings and other activities, as well as timely notices concerning farm crops and animals, have been sent out in manuscript form. These have been

widely copied. The more important events covered and the number of special press notices are as follows:

Farmers' Week	20
Exhibits at the State Fair and at county fairs	29
Miscellaneous	23
Total	72

The Announcer is sent regularly to eight hundred newspapers in the State.

MAILING DIVISION

The Mailing Division is the central mailing agency for the distribution of all official publications of the College. Aside from the old publications and the annual reports of the College, which are sent on request, the Mailing Division handles on an average nearly fifty thousand copies of publications each week. The following statement shows the total number of separate publications, aside from reports, announcements of courses of instruction, and certain other general publications, issued during the year 1912–1913:

Experiment Station bulletins	15
Experiment Station memoirs	2
Experiment Station circulars	8
Reading-Course Lessons for Farm Home	12
Reading-Course Lessons for Farm	12
Announcers	12
Rural School Leaflets	5
Total	66

The mailing lists for the Cornell Reading-Course Lessons for the Farm, the Cornell Reading-Course Lessons for the Farm Home, and the Rural School Leaflets are supervised by the departments of Extension Teaching, Home Economics, and Rural Education, respectively. The mailing lists for the Announcer and for the Experiment Station publications are supervised by the Mailing Division. The mailing list for the Announcer is composed of the lists for both the Reading-Courses and the Experiment Station publications, supplemented by lists of former students of the College, secretaries of the granges in New York State, and eight hundred newspapers. The total number of names on the mailing list for the Announcer amounts to 60,000. The mailing list for the Experiment

Station publications has recently been classified, so that publications will be distributed to persons interested in the subject considered in each bulletin or circular.

The mailing list for Experiment Station publications is increasing each year, and, in spite of the saving made possible by the classification of this list, the editions of bulletins are rapidly exhausted. Of the three hundred and thirty-five bulletins published by the Experiment Station, copies of only thirty-seven are now available for distribution. Thirty-four out of the thirty-seven available have been published since November, 1908; thirty-two out of the thirty-seven have been published within the last three years. Of twenty circulars eight remain, seven of which have been published during the last year. The following is a list of the number of persons in each county in New York State on the mailing list for Experiment Station publications:

Albany	508	Oneida	921
Allegany	431	Onondaga	1,387
Broome	668	Ontario	726
Cattaraugus	638	Orange	514
Cayuga	1,023	Orleans	406
Chautauqua	964	Oswego	693
Chemung	721	Otsego	634
Chenango	504	Putnam	60
Clinton	177	Queens	208
Columbia	276	Rensselaer	323
Cortland	428	Richmond	60
Delaware	385	Rockland	185
Dutchess	463	St. Lawrence	522
Erie	1,258	Saratoga	323
Essex	175	Schenectady	323
Franklin	207	Schoharie	464
Fulton	142	Schuyler	259
Genesee	748	Seneca	395
Greene	169	Steuben	852
Hamilton	6	Suffolk	1,425
Herkimer	317	Sullivan	200
Jefferson	510	Tioga	543
Kings	507	Tompkins	1,280
Lewis	162	Ulster	479
Livingston	471	Warren	100
Madison	626	Washington	315
Monroe	1,454	Wayne	757
Montgomery	262	Westchester	557
Nassau	254	Wyoming	453
New York	1,138	Yates	322
Niagara	568		

Total, 31,846.

The increasing number of publications of the College, together with new post-office requirements for second-class mail matter, has resulted in a corresponding increase in the work of the Mailing Division. This has been largely met by increased efficiency due to the introduction of new and improved mailing machinery, resulting in the elimination of much handwork. Nevertheless, the services of a larger number of persons are required.

The total labor cost, calculated at 15 cents per hour, amounts to $3541.04 as compared with $2112.83 for the preceding year; the grand total operating expense amounts to $5414 as compared with $3888.07 last year. More mail has been received by the Mailing Division, and more publications have been sent on request, than ever before.

Summary of itemized report of Mailing Division

Mail received and publications sent on request

Total mail received (number of pieces)		20,030
Total mail sent out, other than that sent to regular mailing lists (number of pieces)		48,877
Experiment Station bulletins and circulars	20,697	
Reading-Course Lessons for the Farm	22,533	
Announcements	678	
Announcer	3,837	
Reports	654	
Nature-study books	294	
Miscellaneous	184	
Total	48,877	

Cost of mailing to regular lists and of additional work for various departments

Total labor at 15 cents per hour		$3,541.04
Director's Office	$1,970.67	
Experiment Station	210.58	
Reading-Course for the Farm	166.36	
Reading-Course for the Farm Home	201.66	
Extension	434.57	
Rural School Leaflets	233.24	
Announcer	177.21	
Work for departments (based on itemized statement)	146.75	
Total	$3,541.04	
Cost of second-class postage	$1,085.71	
Cost of cartage	266.38	
Cost of stamps	520.87	
		1,872.96
Grand total of operating expenses		$5,414.00

RECOMMENDATIONS

The demand for miscellaneous lectures and lecture courses is on the increase and should be encouraged as much as possible. The lectures should be organized in regular lecture courses so that there may be a logical sequence in any given series. It is recommended that next year an instructor be appointed for the sole purpose of attending to and developing the lecture work.

Another year has definitely proved the worth of extension schools. Despite occasional mistakes, it is recommended that this enterprise be enlarged so that there may be at least two extension schools, during the coming year, in every rural county in the State. This calls for an increase in extension appropriation.

The Experimenters' League has been revived during the past year. This should now be developed so that at least two thousand farmers will be in active cooperation with the College for the purpose of improving their farming methods.

The selection by the county of a county adviser to cooperate with the College has proved of sufficient success to warrant its further development. There are now seventeen of these advisers; there should be one for each rural county in the State. This will eventually demand the time of an additional member of the staff.

The registration for the Farm Reading-Course has materially increased during the past year. The need now is for the organization of study clubs. It is recommended that this work be pushed forward and that necessary assistance be given to enable the Supervisor of the Reading-Course to get in touch with the outside work.

The most pressing need in the organization of extension work is to make a study of the State, county by county, using the Department's geographical list arranged by counties, the county surveys, the county advisers, and other means of obtaining data concerning each county. The State should be districted into at least four main divisions — northern, eastern, southern, and western. For each division there should be at the College one person whose duty it would be to arrange all extension enterprises that the College might undertake for that section. The great mass of correspondence, the details of routine, and the thorough understanding of the needs of one fourth of the State would soon grow beyond the reach of one person. It is recommended that two such persons be appointed this coming year, to actively begin on a program that, for the following year and later, will call for two other persons.

There is evidence that many school-teachers who come to the College for the summer term wish to continue further study at home. They find it impossible to spend sufficient time at the College to pursue the subjects

as they desire. Several of our professors are willing to prepare lessons that may be worked out at home. It is therefore recommended that a correspondence course for such teachers be established next year, and that six lessons be issued in the following subjects: Biology, Soils with reference to Geology, and Farm Botany.

CHARLES H. TUCK,
Professor of Extension Teaching.

DEPARTMENT OF RURAL SCHOOL EDUCATION

TEACHING

No regular courses of instruction were given in the Department during the past year. The extension staff of the Department conducted two courses during the six-weeks summer session of 1913: course D, The School Garden, occupying three hours a week and carrying one hour of university credit; and course F, The School, given five hours a week in two sections and carrying two hours of university credit. There were fourteen students registered in course D and thirty-nine in course F. The classes were held in the model schoolhouse on the campus. Course F was a course in methods, following the work in nature study and elementary agriculture as outlined by the State Syllabus.

INVESTIGATION

There has been no provision for specific investigative work during the past year. This is to be regretted, since the extension work of the Department is in touch with all the rural schools in the State and would find ready cooperation in investigative work in them. It is essential that a more personal relationship be established between the Department and its constituency if the former is to meet intelligently the needs of the latter. During the coming year it is planned to make a beginning in rural school investigation, one member of the Department spending two months in the field.

EXTENSION

The aims of the extension work in the Department were outlined in detail in the last annual report. The same lines of work are being carried forward.

Publications

The means of communication between the Department of Rural School Education and the schools of the State is the Cornell Rural School Leaflet. The September, 1912, number for teachers covered the year's work for 1912–1913 as outlined by the State Syllabus. The edition was 40,000 copies. On May 1, 1913, 37,832 copies had been distributed. All rural teachers and training school pupils were supplied, and about seventy-three per cent of the city and village grade teachers.

During the past year the leaflets were issued as follows:

1. The November leaflet for boys and girls. This comprised twelve pages, and included articles on birds, the potato, poetry and the out-of-doors, trees, Corn Day, and a letter to the children. The original edition

of 100,000 copies was immediately exhausted, and a reprint of 50,000 copies was entirely distributed before the close of the school year.

2. The January leaflet for boys and girls. This issue comprised twenty pages, and included articles on cows, bird boxes, bird migration, books for the rural school, poultry, potatoes, blossoms, certified and pasteurized milk, a fireside talk, and a letter to the children. The edition of 150,000 copies was entirely distributed.

3. In February a special leaflet on agricultural contests was issued. This leaflet was not generally distributed, but was held subject to order by district superintendents. Up to October 1, 1913, 7,209 copies had been distributed. The leaflet, comprising ninety-six pages, contains three articles on organization, and fifteen agricultural contests divided into three groups: (1) Contests based merely on the quality of the product, without relation to the economic value of the crop; in this group are included contests with corn, potatoes, vegetables, flowers, and fruit trees. (2) Contests based on the economic value of the crop as well as on the quality of the product; in this group are included contests with corn, potatoes, oats, clover, vegetables, and small fruits. (3) Contests especially designed for girls, including bread-making, canning, jelly-making, and sewing contests. It should be noted that the policy of centering all contest activity in the hands of local school superintendents has met with universal approval.

4. The March leaflet for boys and girls. This leaflet comprised thirty-two pages, and contained articles on gardens, suggestions for summer work, buying seeds, fruits for the home garden, and the peeper, together with two weather lessons, a chat with boys and girls, and a letter to the children. Of the total edition of 175,000, 155,000 copies were distributed before the close of the school year. The remaining 20,000 copies will be sent this fall to those schools that did not receive them last spring.

5. The September, 1913, leaflet. Prior to October 1, 1913, the new teachers' leaflet for 1913–1914 had already been published and in large part distributed. It covers the topics in nature study and elementary agriculture for study in the rural schools during the coming year, as outlined by the State Syllabus. They are as follows:

Birds: For special study, the robin and the hen. To be recognized, any two winter birds and any five of the following: junco, song sparrow, wren, ovenbird, chimney swift, wood thrush, sandpiper, flicker, catbird, guinea fowl.

Animals: For special study, the cow and the earthworm. To be recognized, any of the following: sheep, weasel, snail, rabbit, deer.

Insects: For special study, the mosquito or the house fly, and one biting and one sucking insect. To be recognized, any four of the following:

wasp, cabbage butterfly, lady beetle, cankerworm, horsefly. (Note: The spider is given for recognition. The ways in which it differs from insects should be learned.)

Plants: For special study, the radish. To be recognized, one of the clovers, one of the grains, one of the grasses, and any six of the following: jack-in-the-pulpit, peach, nasturtium, honeysuckle, vetch, dogtooth violet, laurel, crocus, pumpkin, celery, iris, Solomon's seal; also any four of the following weeds: sour dock, ragweed, beggar-tick, Canada thistle, clotbur.

Trees: For special study, the elm. To be recognized, two kinds of fruit trees, one conifer, and any four of the following: spruce, pine, juniper, plum, apple, walnut, dogwood, maple, sumac, oak, fir, tulip tree.

The articles printed in the September leaflet are as follows: The Enchantment (poem). Part I. Bird Study: The Robin; Birds to be Recognized in 1913–1914; Winter Birds; The Hen; The Types of Combs of the Domestic Fowl; Egg Types; eleven Poultry Lessons; five lessons on the Cow; The Earthworm; Sheep; Weasels; Snails; Rabbits; Virginia Deer. Insect Study: Mosquitoes; The House Fly; May Beetles; Wasps; The Imported Cabbage Butterfly; Lady Beetles; The Kinds of Spiders Most Commonly Seen; Notes on the Cankerworm and the Horsefly. Plant Study: Oats; Growing Oats; Suggestions for the Study of a few Economic Plants to be Recognized in 1913–1914; Five Common Weeds; Plants to be Recognized in 1913–1914. Tree Study: The Elm; The Pines of New York; The Maples of New York; The Oaks of New York; Other Trees to be Recognized in 1913–1914; The Plum; The Peach. Part II. My Purple Hills (poem); Audubon; The Point of View; Manual Training by Means of Agriculture; A Chat with Rural Teachers; Letters from Teachers of Rural Schools; The Distribution of the Cornell Rural School Leaflet; Agricultural Contests; Children's Letters; Corn Day; A Message to New York State Teachers; Helps in the Study of Plants; A Few Common Poisonous Plants; A Word about an Herbarium; Planting of Rural School Grounds; Farm Maps and Farm Layout; Reference Books.

The leaflet comprises 212 pages, with colored frontispiece. It is bound in a heavy gray cover. The edition is 55,000 copies. By September 30, 1913, 42,095 copies had been distributed.

Correspondence

During the year 20,150 pieces of first-class mail were received at the office, and 8542 pieces, including about 3000 circular letters, were sent out. All this correspondence has been looked after by one stenographer. A second stenographer will be employed during the coming year and the

Department hopes to be able to give personal attention to a larger proportion of the letters coming to the office.

Children's letters.— During the year 10,045 letters were received from boys and girls in the rural schools of the State. These were all carefully read, technical questions were answered, and the letters were recorded. A small gift picture was sent to each child from whom three letters were received. One thousand four hundred and fifty children each wrote three letters. The Department cannot encourage correspondence with children in any personal way, for it could not take care of the letters; such an undertaking would require the entire time of a well-equipped person.

Meetings attended

During the year nineteen meetings, with a total attendance of 5325 persons, were attended and addressed by Miss McCloskey. The meetings were mostly conferences of rural teachers called by district superintendents.

Farmers' Week

Conferences for district superintendents and teachers were held in the model schoolhouse on the campus during Farmers' Week.

In addition to the conferences, an exhibit of corn was organized. Four hundred and forty-one rural schools were represented, each by a single ear of corn. There was also a general nature-study exhibit from the third supervisory district of Tompkins county.

Babcock tests

Babcock-test outfits were sent to eight schools, each for a limited time. An outfit was loaned to a district superintendent who demonstrated its use in practically all the schools of her district.

THE OUTLOOK TO THE FUTURE

The extension work with the schools of the State is developing with great rapidity. During 1912–1913 the mailing list for the Cornell Rural School Leaflet more than doubled, reaching a total of over 185,000 persons. There is every indication of a proportionate increase during the coming year. The Department has the cooperation of all of the two hundred and seven district superintendents. There is good feeling for the promotion of any movement looking toward the improvement of school conditions.

RECOMMENDATIONS

Model school building

An appropriation of $3000 has been secured for the erection of a new model schoolhouse on the university campus. The plan is to build a

schoolhouse on a larger scale than would be necessary in a rural district, but in the proper proportions. Such a building is needed here for purposes of educational meetings, conferences with district superintendents, and the like, in addition to housing the departmental staff and equipment. The Department respectfully recommends that an additional appropriation of $2000 be secured for the completion and furnishing of the building, and it is also urged that all possible speed be used in pushing plans and contracts. While the building at Cornell would not be used as a school, it would serve as a demonstration of architecture and equipment, and the rooms could be used for offices and class work of the Department. Consideration of this matter is urged.

Maintenance

On May 1, 1913, a detailed estimate of the funds necessary for the maintenance of the extension work of the Department for the year 1913–1914 was made. This estimate included funds for the publication of the Cornell Rural School Leaflet monthly, for mailing envelopes, supplies, and stationery, and for extra clerical help, manuscripts, photographs, drawings, children's pictures, express, freight, telephone, telegraph, livery, office furniture, traveling expenses, and Farmers' Week. The total amount needed, based on actual data, was $5426.30. The amount of appropriation for this work for the year 1913–1914 is $2500.

The Department is constantly obliged to curtail its work in many ways, particularly as to the number of issues of the Cornell Rural School Leaflet and as to traveling expenses. If the Department is to meet the rapidly growing demands that are being made on it by the school forces of the State, maintenance for another year should be largely increased.

Additional members of the staff

It has long been urged that there be undertaken in the Department certain special lines of work, each under the direction of a single person. Several of these fields need direction at present. The most important are rural school investigation, improvement of school buildings and grounds, school gardens, and agricultural contests. The Department realizes that it is difficult to create a new branch outright; it therefore respectfully recommends that another salaried position be added to this Department, carrying the title of instructor, with a salary of eight hundred dollars the first year.

ALICE G. McCLOSKEY,
Associate in Rural Education.

OCTOBER, 1912 BULLETIN 321

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF THE COLLEGE OF AGRICULTURE

Department of Animal Husbandry

COMPUTING RATIONS FOR FARM ANIMALS

By E. S. SAVAGE

ITHACA, N. Y.
PUBLISHED BY THE UNIVERSITY

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION

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RESPIRATION OF FRUITS AND GROWING PLANT TISSUES IN CERTAIN GASES, WITH REFERENCE TO VENTILATION AND FRUIT STORAGE*

George R. Hill, Jr.

Two or three days before ripening, peaches are very hard. At this time, if handled quickly and carefully they may be shipped long distances without great injury. They owe their hardness to a cellulose-like carbohydrate known as pectose. The cells of the flesh of the peach are relatively very large and the cell walls are thin, but the large quantity of pectose in the cells gives them considerable rigidity. As the peach ripens the pectose is hydrolyzed to pectin, which is a jelly-like gum soluble in the cell sap. This hydrolysis is rapid, and in hot weather a hard peach may become in two or three days so soft that the thin, unsupported cell walls are unable to sustain even the weight of the peach and a flat indentation or bruise is formed on the underside of the fruit.

Mature hard peaches are designated as "market-ripe." When such peaches are placed in cold-storage the rate of softening is greatly decreased; peaches are often kept by this means for two or three weeks, and in some cases longer. At ordinary temperature, about 80° F., a day is often sufficient for them to become as soft as they would in a week in cold-storage at 35° F.

Even though the rate of hydrolysis of pectose can be much decreased by refrigeration, peaches of the best quality cannot be put on the market in distant localities for the following reasons: first, because the temperature in an iced refrigerator car is usually above 10° C. (50° F.), at which point the softening of the peaches is still somewhat rapid; second, because of so-called "ice-scald"; and third, because, in order to be placed on the market in hard condition. the peaches must be picked so green that they have not acquired that richness of flavor found only in peaches ripened on the tree.

If some means of treatment could be found which would arrest this hydrolysis of pectose without otherwise affecting the peach, it would be possible to let the fruit remain on the tree until ripe enough to be really desirable, and still get it to market without serious damage. The demand for peaches would then be greatly increased and the season for them could be extended over a period long enough to avoid glutting the market.

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In September, 1909, the writer was present at an auction sale of a carload of Elberta peaches in Chicago. The fruit had left Palisade, Colorado, in excellent condition. Each peach had been wrapped separately in paper and carefully packed so as to avoid any bruising. The car had been loaded in the customary manner, with an air space around each box in order to insure ventilation. The peaches had come direct to Chicago except for a short stop at Omaha for inspection. When they were taken out of the car at Chicago they were apparently in good condition, although they had softened considerably. They were yellower than when shipped and they brought a good price. In the afternoon of the same day the writer saw some of the peaches on a fruit stand on South Water Street. The fruit appeared slightly darker than in the morning. Some of the peaches were bought, and it was found that the flesh just under the skin was brown in spots. There was no sign of any bruising. The original paper wrappers were on most of the peaches in the box and these peaches showed the browning as much as did those that had been unwrapped. It was plainly not a matter of bruising. The flavor of the peaches was not bad; they were merely insipid and inclined to be mushy, and had the appearance of having been half-cooked. The writer was informed by the dealer that this was " ice-scald " and that it was not uncommon, the brown spots appearing a few hours after the peaches had become warmed to the temperature of the street.

Since the peaches had probably never reached a temperature below 7° C. (45° F.) injury from cold was inconceivable, and the question as to what was the cause of this " ice-scald " was a rather inviting one. Peaches that had been kept in cold-storage at a temperature 5° C. lower than that in the car for a longer period of time were found not to have been so affected.

Injury to peaches shipped in refrigerator cars is common. Not infrequently entire carloads are ruined. The injury is most frequent in the central part of the top tiers of boxes in the car, and it decreases toward the bottom of the car. Since cold air from the ice bunkers is led along the bottom of the car and cools the car by diffusion and circulation upward, the better condition of the peaches in the bottom of the car has been attributed to the lower temperature there. That small differences in temperature between the top and the bottom of the car are sufficient to cause marked differences in the keeping quality of peaches is to be expected, since it is well known that evolution of carbon dioxid and other metabolic phenomena are usually doubled, and not infrequently trebled, in rate by a rise in temperature of 10° C. Oxygen absorption is intensified by a rise in temperature, to about the same degree as is evolution of carbon dioxid. The refrigerator cars are usually kept closed tight and

there is little circulation of air in them. Under such a condition, with a rapid use of oxygen and evolution of carbon dioxid, would not a dearth of the former and an accumulation of the latter probably result? What would be the effect on the peaches of a dearth of oxygen and an accumulation of carbon dioxid? Might the injury to the peaches be due in part to these factors, as well as to the intensified rate of metabolism at the higher temperatures?

From these observations the writer was led to a study of the behavior of fruits and seeds under aerobic and anaerobic conditions. Is the hydrolysis of pectose associated in any way with the intake of oxygen or the evolution of carbon dioxid? Might it be inhibited or retarded by surrounding the fruit by an inert gas such as hydrogen or nitrogen? Relatively, how strong is the anaerobic respiration of fruit as compared with the aerobic? Since carbon dioxid is one of the products of respiration, what would be the effect of its accumulation on the absorption of oxygen and on the metabolic changes mentioned above? What is "ice-scald," and is it connected in any way with aerobic or anaerobic respiration? Is the relation of oxygen to the respiration and metabolism of ripe fruits the same as to that of growing plant tissues? How important is ventilation in the storage and handling of fruit? An attempt is herein made to answer some of the above questions.

SURVEY OF LITERATURE

The following is a brief review of some of the literature of the important phases of anaerobic respiration, together with some current theories offered in explanation of it and of its relation to aerobic respiration.

The continued evolution of carbon dioxid in the absence of oxygen was first observed by Rollo (1798), who at that time was studying the formation of sugar from "mucilages végétaux" in barley grains. In attempting to determine the relation to oxygen of this formation of sugar, he accidentally discovered that the barley grains gave off a considerable quantity of carbon dioxid for several days in the absence of oxygen. De Saussure (1804) noted that *Lythrum* and other green plants gave off carbon dioxid in an atmosphere of nitrogen. Since that time the relation of oxygen to the living organism has been the subject of considerable study, for the reason that this element seems to be the one most indispensably connected with life. Fruits have been used extensively in this study. Several investigators early called attention to the formation of alcohol in fruits that were kept in a chamber containing no oxygen, but these fruits were not kept free from contamination by yeasts; hence, the production of alcohol by the tissues of the fruit was not established.

(1798) Rollo, —. Expériences et observations sur le sucre. Ann. d. chim. 25: 37–50.
(1804) De Saussure, Th. Des plantes qui peuvent végéter dans le gaz azote. Recherches chimiques sur la végétation, 197–208.

Bérard (1821) noted that green fruits ripened when kept in air. When oxygen was withheld, the fruits were unable to ripen; the ripening process was resumed, however, when the fruits were again placed in the air, if they had not been kept too long in the oxygen-free atmosphere.

Cahours (1864) studied oranges kept in air and in nitrogen and noted that carbon dioxid was evolved in both atmospheres.

Lechartier and Bellamy (1869) found that apples kept in an oxygen-free chamber evolved carbon dioxid for about eight months and that alcohol also was formed almost equaling the carbon dioxid in amount. Pasteur (1872) called attention to the fact that the ratio of this production of alcohol and of carbon dioxid was the same as that in alcoholic fermentation. Lechartier and Bellamy (1872) immediately repeated their work and succeeded in obtaining alcohol from the center of some apples, to which place it was impossible for yeast to have gone. This is probably the first undisputed proof of the formation of alcohol by higher plant tissues. It is the first indication in literature of the close relationship between anaerobic respiration and alcoholic fermentation.

Pfeffer (1878) proposed the name "intramolecular respiration" for that respiration occurring in the absence of oxygen, because the energy and the carbon dioxid come from the destruction of the molecule from which the carbon dioxid arises. He held that aerobic and intramolecular respiration were genetically connected, and that the existence of the intramolecular respiration was the reason for the aerobic. This view was strengthened when Pasteur found alcohol in the inner cells of an apple that had been kept in air. It has been shown later, however, that this connection is not so close as Pfeffer believed.

Buchner (1897) gave great impetus to the study of the nature of anaerobic respiration when he showed that the yeast organism contains an enzyme, zymase, which is capable of transforming glucose into alcohol and carbon dioxid.

Godlewski and Polzeniusz (1901) attempted to determine whether various seeds contained zymase. They found that in the absence of oxygen, carbon dioxid and alcohol are formed in rather large quantities and in nearly the proportion in which they are formed in alcoholic fermentation This proportion is expressed in the following equation:

$$C_6H_{12}O_6 + \text{fermentation} = 2\ CO_2 + 2\ C_2H_5OH$$

(1821) Bérard, —. Du mémoir sur la maturation des fruits. Ann. chim. phys. 16: 225–251.
(1864) Cahours, A. Sur la respiration des fruits. Compt. rend. 58: 653–656.
(1869) Lechartier, G., et Bellamy, F. De la fermentation des fruits. Compt. rend. 69: 466–469.
(1872) Pasteur, L. Note sur la production de l'alcool par les fruits. Compt. rend. 75: 1054–1056.
(1872) Lechartier, G., et Bellamy, F. De la fermentation des fruits. Compt. rend. 75: 1203–1206.
(1878) Pfeffer, W. Das Wesen und die Bedeutung der Athmung in der Pflanze. Landw. Jahrb. 7: 805–834.
(1897) Buchner, E. Alkoholische Gährung ohne Hefezellen. Ber. d. deut. chem. Gesell. 30[1]: 117–124.
(1901) Godlewski, E., und Polzeniusz, F. Über die intramoleculare Athmung von in Wasser gebrachten Samen und über die dabei stattfindende Alkoholbildung. Bul. Acad. Sci. Cracovie (1901): 227–276.

Since two molecules of each substance are formed, the theoretical ratio in which they may be formed is the ratio of the molecular weight of the carbon dioxid to the molecular weight of the alcohol. This is:

$$\frac{C_2H_5OH}{CO_2}=\frac{46}{44}=\frac{104.5}{100}$$

This ratio means that for each 100 parts by weight of carbon dioxid produced, theoretically 104.5 parts by weight of alcohol will be produced. These authors found that when soaked peas are placed in glucose or cane sugar solutions, some of the sugar disappears and the increase in the amount of carbon dioxid and alcohol produced corresponds very closely to the amount of sugar lost. This indicates clearly that pea seeds are capable of producing alcoholic fermentation. The authors were unable to isolate zymase from the seeds, but their work gave great impetus to other investigators.

Stoklasa and Czerny (1903), by pulping sugar beets, potatoes, and the like, and by subjecting the pulped tissue to a pressure of 300 atmospheres, succeeded in getting an enzyme possessing the properties of Buch er's zymase. These authors reported also that they had isolated zymase from peas and from the muscle, heart, lungs, liver, and kidney of beef, and since that time Stoklasa and his students have isolated zymase from a wide range of plant and animal tissues.

Nabokich (1903) held that there are two kinds of intramolecular respiration; that one is a true alcoholic fermentation of glucose; and that the other is a fermentation of glucose with the additional use of organic acids, such as lactic acid, and various other organic compounds, resulting in a large excess of carbon dioxid over alcohol. This points to the opinion that alcoholic fermentation is only a part of anaerobic respiration.

Stoklasa, Ernest, and Chocenský (1906) found that the $\frac{C_2H_5OH}{CO_2}$ ratio for sugar beets, potatoes, apples, and bean and vetch seeds under anaerobic conditions varies not further than 10 to 20 from the theoretical 104.5. From sugar beets these investigators isolated noticeable quantities of lactic acid. They concluded that in most cases anaerobic respiration is an enzymatic process identical with alcoholic fermentation. They found also that in the case of sugar beets the intensity of anaerobic respiration for the temperatures 1° to 3° C., 18° to 20° C., and 30° to 32° C. varies between .358 and .6 of the intensity of normal respiration.

(1903) Stoklasa, J., und Czerny, F. Isolierung des die anaërobe Athmung der Zelle der höher organisierten Pflanzen und Tiere bewirkende Enzyms. Ber. d. deut. chem. Gesell. 36[1]: 622–634.

(1903) Nabokich, A. J. Über die intramolekulare Atmung der höheren Pflanzen. Ber. d. deut. bot. Gesell. 21: 467–476.

(1906) Stoklasa, J., Ernest, A., und Chocenský, K. Über die glykolytischen Enzym im Pflanzenorganismus. Zeitsch. physiol. Chem. 50: 303–360.

Several other investigators found in anaerobic respiration a similar production of alcohol and carbon dioxid, which led to the contention that anaerobic respiration is identical with alcoholic fermentation. It has been shown, however, in the papers subsequently cited, that, while alcoholic fermentation does explain a large part of the production of carbon dioxid in anaerobic respiration, it by no means explains all.

Palladin (1905) contends that carbon dioxid arises from plants under anaerobic conditions in three different ways:

1. "Nukleokohlensäure," so called because production of carbon dioxid follows closely the curve of the total nucleo-proteids. This is caused by enzymes, some of which are soluble in the juice and some of which are insoluble. The latter are possibly combined with the protoplasm. Zymase is placed in this group.

2. "Reizekohlensäure," that which is formed directly by the protoplasm itself, due to various stimuli such as quinine hydrochlorid and ether. These two stimuli were applied, one to etiolated vetch shoots in 10-per-cent cane sugar solution and the other to gladiolus bulbs. The series with the stimulus gave about twice as much carbon dioxid in each case as did the check. Both series were then frozen in order to kill the protoplasm, and the stimulants were again applied. They had no effect after the freezing.

3. "Oxydasekohlensäure," that carbon dioxid which is formed by the action of various oxidases. When hydrogen peroxid (H_2O_2) was added to the extracted juice of gladiolus bulbs, a marked increase occurred in evolution of carbon dioxid. When pyrogallic acid was added to this, the evolution of carbon dioxid became very strong.

Palladin and Kostytschew (1906) found that frozen tops of etiolated *Vicia faba* plants in a stream of hydrogen gave the very low $\frac{C_2H_5OH}{CO_2}$ ratio of 17.1, 18.5, and 8.4, and of only 33 when placed in sugar solution. Other examples are given showing that, while alcohol production is dependent on the amount of zymase present, the production of carbon dioxid is not so dependent.

Kostytschew (1908) found that *Agaricus campestris* gives an abundant evolution of carbon dioxid under anaerobic conditions, but no alcohol. Neither is alcohol produced when a glucose solution is added. This shows that zymase is not present in *Agaricus*; but, since anaerobic respiration continues, it suggests also that alcoholic fermentation is only one phase of the phenomenon.

(1905) Palladin, W. Über den verschiedenen Ursprung der während der Atmung der Pflanzen ausgeschiedenen Kohlensäure. Ber. d. deut. bot. Gesell. 23: 240–247.
(1906) Palladin, W., und Kostytschew, S. Anaerobe Atmung, Alkoholgärung, und Acetonbildung bei den Samenpflanzen. Zeitsch. physiol. Chem. 48: 214–239.
(1908) Kostytschew, S. Zweite Mitteilung über anaërobe Atmung ohne Alkoholbildung. Ber. d. deut. bot. Gesell. 26a: 167–177.

It has also been shown by a number of investigators that a wide range of carbon-containing compounds, not fermentable by zymase, can be used by plant tissue in the anaerobic production of carbon dioxid.

Since zymase seems to be so widely distributed in the tissues of plants, the idea of its having some particular function in aerobic forms cannot but suggest itself. Kostytschew (1908 and 1910) has given considerable experimental data and has proposed some hypotheses with reference to the subject. He showed that alcohol is produced under aerobic conditions only in the parts that are most poorly aerated. If alcoholic fermentation is a step in normal respiration, alcohol should be used by the organism at least as readily as glucose. In Kostytschew's experiments alcohol was found to be used with great difficulty or not at all, and neither could lactic acid be used. Both had a retarding effect on the production of carbon dioxid. Kostytschew concluded that alcoholic fermentation is the first step in normal respiration, but that under aerobic conditions it goes only as far as the formation of an easily oxidizable substance between the glucose and the lactic acid and alcohol. In the absence of oxygen this fermentation continues to the production of lactic acid and alcohol, but not normally under aerobic conditions. Kostytschew called alcohol and lactic acid "Nebenproducte," not "Zwischenproducte," of respiration. He succeeded in showing that a glucose solution, completely fermented by zymin* and freed from any proteins and peptones, contains an easily oxidizable substance that will reduce Fehling's solution. The nature of this substance is unknown. Kostytschew showed also that the production of carbon dioxid is markedly increased by surrounding seeds or other plant tissues with a zymin-fermented solution. Considerable attention is also given by this author to the relation of oxidases to the process of respiration.

Palladin (1909) has attempted to explain the various phenomena of respiration. He divides all such phenomena into two classes — primary and secondary. In the primary class, the materials of respiration are broken down into simple products without the use of oxygen, by means of enzymes. The chemical reactions consist of phenomena of reduction and oxidation similar to those of dry distillation, and occur at the expense of the combined oxygen within the cells. Glucose and other stable substances are used and various more easily oxidizable products arise. Alcohol is produced only in absence of oxygen, but with good aeration the labile intermediate products are oxidized before the alcohol stage is reached. In the secondary class of respiration phenomena Palladin places the

* Zymin is a commercial preparation made by drying yeast cells with acetone and ether. The protoplasm is killed in the process, but the zymase is presumably little affected.

(1908) Kostytschew, S. Über die Anteilnahme der Zymase am Atmungsprozesse der Samenpflanzen. Biochem. Zeitsch. 15: 164–195.
(1909) Palladin, W. Über das Wesen der Pflanzenatmung. Biochem. Zeitsch. 18: 151–206.
(1910) Kostytschew, S. Über den Vorgang der Zuckeroxydation bei der Pflanzenatmung. Zeitsch. physiol. Chem. 67: 116–137.

various oxidation processes. He holds that these are maintained largely by oxidases and similar enzymes.

Since it had been shown by a number of investigators that a wide range of organic compounds were used in anaerobic respiration, and since Palladin had called attention to a production of carbon dioxid in certain cases which varied directly with the nucleo-proteids, and since others had indicated that proteins might be used in anaerobic respiration the same as glucose, Godlewski (1911) undertook to determine to what extent production of carbon dioxid could be correlated with protein decomposition. He concluded that anaerobic decomposition of protein proceeds independently of intramolecular respiration; that it is an enzymatic process which continues long after the evolution of carbon dioxid has ceased, and after the death of the protoplasm. He found also that sugar increases the rate of evolution of carbon dioxid but hinders the rate of protein decomposition. Citric acid markedly decreases the output of carbon dioxid.

An increase of temperature was found by von Chudiakow (1894) to increase the rate of anaerobic production of carbon dioxid according to the Van't Hoff-Arrhenius law, just as in aerobic respiration. Von Chudiakow came to the conclusion that in anaerobic respiration the total amount of carbon dioxid produced is the same whether at high or low temperatures, the evolution at low temperatures continuing for a sufficiently longer time to make up for the difference in rate. In order to determine the effect of temperature, von Chudiakow heated the object for a given length of time to a given temperature, then raised the temperature to that next desired, and so on. Palladin (1899) pointed out that when a plant is heated to any temperature and then cooled to the original temperature, the rate of respiration will not be the same as that before the heating. The work of von Chudiakow has been objected to on this ground by some investigators, but Kuyper (1909–1910) found that temperature does not become injurious until it goes above 25° C. or thereabout, varying with the kind of tissue used. Below 25° C. Kuyper found the ratios to vary directly with the temperature. This gives weight to the work of von Chudiakow, although there is still the objection that the time interval which he used was rather short.

Pourievitch (1905) has shown that the age of the particular plant and the amount of nutritive material that it contains, together with other

(1894) von Chudiakow, N. Beiträge zur Kenntniss der intramolekularen Athmung. Landw. Jahrb. 23: 333–389.
(1899) Palladin, W. Influence des changements de température sur la respiration des plantes. Rev. gén. bot. 11: 241–257.
(1905) Pourievitch, K. Influence de la température sur la respiration des plantes. Ann. sci. nat. (IX) 1: 1–32.
(1909–1910) Kuyper, J. The influence of temperature upon the respiration of higher plants. Proc. Sec. Sci. Roy. Acad. Sci. Amsterdam 12: 219–227.
(1911) Godlewski, E. Über anaerobe Eiweisszersetzung und intramolekulare Atmung in den Pflanzen. Bul. Acad. Sci. Cracovie (1911): 623–717.

considerations, modify rather markedly the sensitiveness of the plant to temperature changes. This would affect von Chudiakow's results, since he used one set of material for several changes of temperature.

The absence of oxygen is very quickly manifested on growth, which ceases almost abruptly. Takahashi (1905), Crocker (1907), Nabokich (1909), Lehmann (1911), Shull (1911), and others have studied growth in the complete absence of oxygen and in small amounts of it. Growth in the absence of oxygen is reported in the cases of a fairly large number of the higher plants, but not in all under the conditions tried. This growth, however, is so slight as to be insignificant, and it seems to be influenced by many factors besides oxygen, such as nutrition, temperature, age, carbon dioxid, and the like.

The reversibility of chemical reactions holds for enzymatic transformations as well as for inorganic chemical ones. The rate of chemical reaction decreases with an accumulation of the products of the reaction until the reaction finally ceases. This is true in respiration. Kostytschew (1910) showed that alcohol materially decreased the rate of anaerobic respiration. The effect of an accumulation of carbon dioxid is manifested in a variety of ways. De Saussure (1804) found that bean plants withered directly in an atmosphere of two thirds or more carbon dioxid. In 50 per cent carbon dioxid they were dead in seven days; in 25 per cent they lived ten days with no growth; and they grew much better in 8½ per cent carbon dioxid than in 12½ per cent, in sunlight. Loproire (1895) studied the effect of carbon dioxid on the growth of molds, yeasts, pollen tubes, and the like, and found considerable variation. When 25 per cent oxygen was present in the gas, carbon dioxid inhibited the growth of pollen tubes only when present in large amounts. Different kinds of pollen showed wide variation. Mangin (1896) placed starchy and oily seeds in various stages of germination in atmospheres of 1 to 3 per cent and 4 to 5 per cent carbon dioxid. Both evolution of carbon dioxid and absorption of oxygen were decreased in the latter case; likewise the $\frac{CO_2}{O_2}$ ratio was raised, indicating that the carbon dioxid had decreased absorption of oxygen more than evolution of carbon dioxid.

(1804) De Saussure, Th. Influence du gaz carbonique sur la végétation. Recherches chimiques sur la végétation, ..25–34.
(1895) Loproire, G. Über die Einwirkung der Kohlensäure auf das Protoplasma der lebenden Pflanzenzelle. Jahrb. wiss. Bot. 28: 531–626.
(1896) Mangin, L. Sur la végétation dans une atmosphère viciée par la respiration. Compt. rend. 122[1]: 747–749.
(1905) Takahashi, T. Is germination possible in absence of air? Bul. Col. Agr. Tokyo 6: 439–442.
(1907) Crocker, William. Germination of seeds of water plants. Bot. Gaz. 44: 375–380.
(1909) Nabokich, A. J. Temporäre Anaërobiose höherer Pflanzen. Landw. Jahrb. 38: 51–194.
(1910) Kostytschew, S. Über den Vorgang der Zuckeroxydation bei der Pflanzenatmung. Zeitsch. physiol. Chem. 67: 116–137.
(1911) Lehmann, E. Zur Kenntnis des anaeroben Wachstum höherer Pflanzen. Jahrb. wiss. Bot. 49: 61–90.
(1911) Shull, C. A. The oxygen minimum and the germination of Xanthium seeds. Bot. Gaz. 52: 453–477.

Gore (1911 and 1912) and Lloyd (1911) have shown that carbon dioxid applied to persimmons has the effect of destroying the astringency, due presumably to a transformation of the tannin into an insoluble compound. The length of time necessary for this transformation varied widely with different sorts. Softening was usually retarded during the process but increased noticeably when the process was finished. Some varieties colored more quickly after the treatment, while others were not thus affected. The flesh of the fruit darkened somewhat after the treatment, particularly if it was carried a little too far. The flavor in a number of cases was slightly inferior to that of the unprocessed fruits. At ordinary temperatures the processed fruit perished in most cases quicker than the unprocessed. These experiments show that carbon dioxid materially affects several of the metabolic functions.

Gerber (1903) noted that an increased percentage of oxygen increased the respiratory quotient and hastened the maturation of unripe bananas, but decreased the respiratory quotient in ripe bananas. Whenever this fell below unity in the case of ripe fruits, the aroma was decreased. This, Gerber thinks, is because the alcohols, which otherwise produce volatile oils, are oxidized.

Powell and Fulton (1905) made a study of apple scald. This, they think, is a physiological breakdown of the tissues of the fruit, probably due to oxidizing enzymes. It is described as a browning of the flesh just under the skin, giving a semi-baked appearance to the fruit. It is very common on some varieties of apples kept in cold-storage, more than fifty per cent of the fruit being affected in some cases. These authors found that immature fruit is much more subject to scald than is mature, well-colored fruit. Fruit that is not stored for several days after having been picked in hot weather scalds badly in storage. In the study here referred to, paper wrappers did not reduce the scald but paraffined wrappers are reported to have done so. Air containing formaldehyde, sulfur dioxid, chlorin, alcohol, ether, chloroform, or turpentine had no effect on the scalding of Ben Davis apples but the apples were injured in several cases. The scald was increased in an atmosphere of moist oxygen, but was entirely prevented in an atmosphere of nitrogen for nine days. It was retarded

(1903) Gerber, M. C. Influence d'une augmentation momentanée de la tension de l'oxygène sur la respiration des fruits a éthers volatils, pendant la période ou, murs, ils dégagent un parfum. Compt. rend. soc. biol. 55: 267–269.
(1903) Gerber, M. C. Respiration des fruits parfumés lors de leur maturation complète, quand on les place a l'état vert et non parfumés dans de l' air enrichi en oxygène. Compt. rend. soc. biol. 55: 269–271.
(1905) Powell, G. H., and Fulton, S. H. The apple in cold storage. U. S. Dept. Agr., Bur. Plant Indus. Bul. 48: 1–64.
(1911) Gore, H. C. Experiments on the processing of persimmons to render them nonastringent. U. S. Dept. Agr., Bur. Chem. Bul. 141: 1–31.
(1911) Lloyd, F. E. Carbon dioxide at high pressure and the artificial ripening of persimmons. Science n. s. 34: 924–928.
(1912) Gore, H. C. Large scale experiments on the processing of Japanese persimmons. U. S. Dept. Agr., Bur. Chem. Bul. 155: 1–20.

when the fruits were placed in water or covered with vaseline, paraffin, or olive oil. The apples had been kept in cold-storage for several months prior to the experiments. Neither the duration of these experiments nor the temperature employed is given.

It is not the purpose of the writer to consider the literature critically or to criticise the many interpretations that may be placed on the publications mentioned above. All that is desired is to suggest a few of the concepts which seem to be prominent in the literature.

From this brief review it is apparent that many widely different katabolic processes occur in plant tissues in the absence of oxygen; that these katabolic processes are maintained largely by enzymes; that there is a profuse and frequently long-continued evolution of carbon dioxid as a result of these processes; that the carbon dioxid is produced by a variety of enzymes and probably in some cases partly by the living protoplasm itself; that the carbon dioxid arises principally from the decomposition of sugar by zymase; that a considerable quantity of carbon dioxid arises from the decomposition of fats, of certain cyclic compounds, and of many other organic substances by means of the various enzymes; that, besides the processes producing carbon dioxid, there are others, such as protein decomposition, which proceed independently and in some cases last longer; that alcohol, lactic acid, glycerin, and other materials are produced, depending on the presence of zymase and of suitable carbohydrates; that production of carbon dioxid and other processes are materially affected by various substances, as salts, acids, alkalies, alcohol, carbon dioxid, and various stimulants, and by changes in temperature.

EXPERIMENTAL WORK

RESPIRATION OF FRUITS AND GERMINATING SEEDS IN HYDROGEN, NITROGEN, AND AIR

Studies were made of the production of carbon dioxid in hydrogen, in nitrogen, and in air by ripe cherries, blackberries, green peaches, ripe grapes, and germinating wheat. The hydrogen was obtained from a cylinder of the compressed gas furnished by the Department of Physics at Cornell University. The nitrogen, or oxygen-free air, was obtained by passing air over red-hot copper in a combustion furnace. The air was obtained from an automatic electric pump attached to a compression tank. The hydrogen and the nitrogen were each passed through three wash-bottles containing potassium pyrogallol renewed often enough to insure freshness. This removed traces of oxygen and of carbon dioxid. The nitrogen was so free from oxygen that the alkalin pyrogallol was not darkened noticeably by it in a half-hour. The hydrogen was made elec-

trolytically and before passing through the alkalin pyrogallol it contained only a very slight amount of oxygen. The air was passed through a wash-bottle containing a solution of potassium hydroxid (KOH). All three gases were passed through wash-bottles containing water before they entered the respiration chambers. This prevented a backward absorption of the carbon dioxid.

The respiration chambers consisted of glass bottles each having a capacity of 250 cubic centimeters. Each bottle was fitted with a two-holed rubber stopper. A glass tube extending just through the stopper led the gas into the chamber, and another glass tube reaching to the bottom of the chamber drew the gas away. The gas was led from the respiration chamber through a jar of calcium chlorid and then through a Mohr potash bulb, in which the carbon dioxid was collected and weighed. In order to prevent absorption of moisture from the air by the potash bulb, the gas, on leaving the bulb, was led through another jar of calcium chlorid.

The temperature was controlled to within ½° C. by placing the respiration bottles in water in a basin constructed for the purpose. The water was heated by an electric heater of nichrome ribbon; and the temperature was controlled by connecting a mercury thermostat with a gravity cell and a telegraphic relay in such a manner that the current through the heater would be automatically turned off or on at any desired temperature. An electric motor was used for running a stirrer by means of which the temperature of the water was kept uniform throughout.

The respective gases were conducted in glass tubes with very close connections of rubber tubing. The experiments were always run in triplicate. The stream of gas through each chamber was regulated to about 500 cubic centimeters per hour. The potash bulbs were weighed usually twice daily and the hourly rate computed from the weights thus found.

The fruits in each respiration chamber were carefully weighed, and were sterilized when it was possible to do this without injury to the fruit. An equal number of fruits were used in each case, and the amount used generally weighed about fifty grams. The data were then all computed on the one-hundred-gram basis for comparison.

The Roman numerals I, II, and III were used for designating the series in air, in nitrogen, and in hydrogen, respectively, and the letters a, b, and c were used for the individual members in each series: thus, Ia, Ib, and Ic indicate the series in air; IIa, IIb, and IIc, the series in nitrogen; and IIIa, IIIb, and IIIc, the series in hydrogen. The denotation of any series in addition to these will be found with that series.

Respiration of ripe cherries

Well-ripened Duke cherries were used. These were sound cherries, carefully chosen. The flesh was firm and the cherries were sour. Fifteen cherries were chosen for each test, their aggregate weight being about 50 grams. Each stem was cut about one centimeter from the fruit. The fifteen cherries were placed in cheesecloth, dipped in 95-per-cent alcohol then twice in sterile water, and placed in the sterile respiration chambers. The gases were passed through the chambers for one hour before the collection of carbon dioxid began.

There were two series of these cherries. The first was kept in a continuous current of the respective gases. The second was surrounded by the respective gases and a current passed through for one half-hour twice daily, in order to remove the carbon dioxid. The first series (Table 2A) is designated by the Roman numerals and letters Ia, Ib, and Ic for air, IIa, IIb, and IIc for nitrogen, and IIIa, IIIb, and IIIc for hydrogen, as already described; the second series (Table 2B) is designated by IVa, IVb, and IVc for air, Va, Vb, and Vc for nitrogen, and VIa, VIb, and VIc for hydrogen. The temperature was 30° C. throughout.

The series was started on July 13 and continued for two and one half days. Five determinations of carbon dioxid from each were taken. In Table 1 are given the weights of each group of fifteen cherries. In tables 2A and 2B are given the number of hours of each run, the amount of carbon dioxid in milligrams per hour for each 100 grams of cherries, for each period and for the entire period, and the ratios of the weights of carbon dioxid produced in nitrogen and hydrogen to that produced in air.

TABLE 1. WEIGHT OF THE FIFTEEN CHERRIES IN EACH RESPIRATION CHAMBER

Groups	Grams	Groups	Grams
Ia	49.7	IVa	44.6
Ib	51.0	IVb	51.2
Ic	48.0	IVc	46.6
IIa	48.5	Va	45.9
IIb	48.0	Vb	46.6
IIc	47.7	Vc	46.2
IIIa	46.8	VIa	44.9
IIIb	50.0	VIb	48.3
IIIc	48.2	VIc	46.0

TABLE 2A. AVERAGE HOURLY PRODUCTION OF CARBON DIOXID IN MILLIGRAMS PER 100 GRAMS OF RIPE CHERRIES IN AIR, NITROGEN, AND HYDROGEN AT 30° C. IN CONTINUOUS CURRENT OF RESPECTIVE GASES

Period	1	2	3	4	5	Average
	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period....	8.5	10.5	15.0	9.5	14.0	*57.5
Groups in air	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
Ia	8.8	12.6	12.2	13.9	13.9	12.5
Ib	Lost	8.6	16.8	16.9	18.1	15.6
Ic	12.9	15.4	12.7	13.7	16.6	14.4
Average.........	10.8	12.2	13.9	14.8	16.2	14.2
	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period....	10.0	10.0	15.5	9.5	14.0	*59.0
Groups in nitrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIa	11.2	11.0	10.1	10.4	8.1	10.0
IIb	13.7	13.9	12.8	14.1	11.7	13.1
IIc	17.7	15.7	11.2	14.0	9.0	13.0
Average.........	14.2	13.5	11.4	12.8	9.6	12.0
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$†	1.31	1.11	.81	.86	.59	.85
	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period....	11.0	10.0	15.5	9.5	14.0	*60.0
Groups in hydrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIIa	11.6	11.5	13.7	12.7	11.8	12.4
IIIb	10.1	12.3	13.4	9.3	10.2	11.3
IIIc	9.9	13.4	9.7	9.7	8.9	10.2
Average.........	10.5	12.4	12.3	10.6	10.3	11.3
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$	.97	1.02	.88	.72	.64	.80

* Total hours, not average.
† Ratio of anaerobic respiration to normal respiration.

TABLE 2B. AVERAGE HOURLY PRODUCTION OF CARBON DIOXID IN MILLIGRAMS PER 100 GRAMS OF RIPE CHERRIES IN AIR, NITROGEN, AND HYDROGEN AT 30° C. IN CURRENT OF RESPECTIVE GASES FOR ONE HALF-HOUR TWICE DAILY

Period	1	2	3	4	5	Average
	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period....	12.0	9.5	16.5	8.5	14.0	*60.5
Groups in air	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IVa..................	10.8	12.8	12.9	14.2	14.2	13.0
IVb..................	Lost	Lost	Lost	9.8	11.5	....
IVc..................	11.6	12.0	11.9	11.4	10.4	11.5
Average.........	11.2	12.4	12.4	11.8	12.0	12.2
	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period....	13.5	9.5	16.5	8.5	14.0	*62.0
Groups in nitrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
Va..................	13.2	13.2	10.6	9.2	8.0	10.8
Vb..................	11.1	10.2	10.0	8.3	6.8	9.3
Vc..................	10.6	11.2	10.3	8.4	7.8	9.7
Average.........	11.6	11.5	10.3	8.6	7.5	9.9
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$....................	1.04	.93	.83	.73	.63	.81
	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period....	13.5	10.0	16.0	8.5	14.0	*62.0
Groups in hydrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
VIa..................	13.6	12.9	11.5	10.5	8.3	11.3
VIb..................	10.0	11.8	10.8	10.1	8.7	10.2
VIc..................	12.2	11.6	11.2	11.5	10.1	11.2
Average.........	11.9	12.1	11.2	10.7	9.0	10.9
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$....................	1.06	.98	.90	.92	.75	.89

* Total hours, not average.

It will be seen from Table 1 that there was considerable diversity in the weights of the several groups of 15 cherries, notwithstanding the fact that the cherries had been chosen with a view to uniformity. The cherry stones were more nearly uniform in weight than were the whole cherries, consequently the proportion of flesh in Ib, weighing 51 grams, was greater than in IIIa, weighing 46.8 grams. The cherries were not all from the same tree. Some were from shaded parts of a tree and some from well-lighted parts. Some came from heavily loaded limbs and others from limbs bearing only a few cherries. All such factors cause the water content, the acid content, the sugar content, and presumably the enzymatic content of the fruit to vary; and since all such factors influence the production of carbon dioxid a wide variation is to be expected, no matter how uniformly the fruits may be grouped together after having been picked. The same applies to all the other fruits used, and is probably sufficient to explain a large part of the individual variations in the rates of evolution of carbon dioxid.

Another cause of individual variation was as follows: The flow of gas through each chamber was regulated by a pinchcock so as to give about two to three bubbles per second through the potash bulbs. Sometimes, in the absence of the operator, a jar of calcium chlorid or a potash bulb would become sufficiently clogged to decrease this rate by perhaps half and increase the others correspondingly. This would slightly increase the amount of carbon dioxid collected in the one case and slightly decrease it in the others. In the following run the carbon dioxid that had accumulated in the chambers through which the gas flow was slowest would be caught, and this would give those chambers a correspondingly higher rate for that period. At times the temperature of the room was considerably colder than at other times. While this would not affect the respiration chambers, it would affect the temperature of the gases in the tanks and thus cause a variation in the rate of flow.

The method of calculating and expressing the data in tables 2A and 2B and the other similar tables is as follows: The different periods are expressed by the numerals 1, 2, 3, 4, and 5 in a horizontal row, and just under the number of each period is given the number of hours duration of that period. The total number of hours of the entire period is given at the right of this row. The members of each series, Ia, Ib, Ic, or IIa, IIb, IIc, and so on, are arranged in a column, and the number of milligrams of carbon dioxid produced by each member in each period is placed under the corresponding period number. In the last column the average of each member for the entire period is given. Below the members of the series is given the average of the triplicates for each period. In the nitrogen and hydrogen series, the ratio of anaerobic production of carbon dioxid to normal production, expressed as $\frac{An}{N}$, is given for each period.

This was obtained by dividing the average rate for each period in those gases by the corresponding rate in air.

In Table 2A a number of things are shown very markedly, despite the individual variations:

1. About the same amount of carbon dioxid was produced in nitrogen as in hydrogen. Hence neither of these gases hinders anaerobic respiration of ripe cherries more than the other.

2. Approximately as much carbon dioxid was produced during the first thirty-six hours in both nitrogen and hydrogen as in air. The production of carbon dioxid in ripe cherries is apparently caused by processes quite independent of the absorption and use of oxygen, since the rate is maintained so well in hydrogen and nitrogen and is as great as that in air to begin with.

3. The hourly rate of evolution of carbon dioxid during the sixty hours decreased only slightly in nitrogen and scarcely any in hydrogen, while it increased rather markedly in air. The increase in air was probably not due to a yeast or other infection, since such an infection at once gives a very rapid increase in evolution of carbon dioxid, such as was not found in this case. It is possible that at 30° C. the ripening of fruit is attended by a production of various carbon-dioxid-producing enzymes which is favored by oxygen, and that an increased production of these enzymes might account for the increased rate of evolution of carbon dioxid in air.

In order to obtain the ratio of anaerobic respiration to normal respiration, the average hourly production for each period in nitrogen and in hydrogen was divided by the corresponding average in air. The ratio is written $\frac{An}{N}$. It declines markedly in both nitrogen and hydrogen after the second period, although it was slightly greater than unity during that period. The apparent decline is due not so much to a reduction in the hourly rate in nitrogen and hydrogen as to an increase in the rate in air.

The vertical column of averages at the right was obtained by dividing the total amount of carbon dioxid produced in each case by the total number of hours. The average rate in both nitrogen and hydrogen is seen to be about the same as the individual rates in those series.

In Table 2B are given the results with a series identical with those used for Table 2A, except that the gases were drawn through the respiration chambers twice daily for one half-hour only, in order to remove the carbon dioxid for determination.

In all three members of the nitrogen series there is a decline in the hourly rate after the first two periods. There is a slight decline in the hydrogen series. In air the rate is more nearly uniform, with a tendency to rise, and the hourly rates for the first two periods in air are again about the same as in nitrogen and hydrogen. The average rates are slightly lower than in the corresponding series shown in Table 2A. This is probably due to an accumulation of carbon dioxid in the chambers between the runs.

At the end of the experiments the cherries kept in nitrogen and in hydrogen gave a strong iodoform test for alcohol and also had a slightly fermented flavor. They were a trifle bleached in spots; otherwise, no difference could be seen between them and those kept in air.

These experiments seem to show that for a considerable period of time the respiratory processes in ripe cherries are about as active in the absence of oxygen as in the presence of it. This hypothesis seems to suggest that these processes might be maintained for the most part by enzymes and probably not to any great extent by the living protoplasm. In spite of the high probable error due to difference in the hourly rate of evolution of carbon dioxid, some reasons for which have already been pointed out, the triplicate experiments herein described seem to point consistently to the above conclusions.

Respiration of blackberries

A series of experiments similar to those with cherries was run with ripe blackberries. The surfaces of these fruits were so uneven that they could not be sterilized. The first period of their respiration, however, gave a yield of carbon dioxid as great in both nitrogen and hydrogen as in air. No tables for the blackberries are given for the reason that because of micro-organisms the evolution of carbon dioxid became too irregular after the first period to be of any value.

Respiration of green peaches

A series with green peaches taken just at the time when the stone was hardening, at which time the fruits were about half grown, was run in order to see the behavior of the green growing tissue. The same respiration chambers were used as with the other fruits.

Three peaches were placed in each respiration chamber. The weight of the peaches in each chamber is given in Table 3:

TABLE 3. WEIGHT OF THE THREE GREEN PEACHES IN EACH RESPIRATION CHAMBER

Groups	Grams
Ia	57.4
Ib	58.8
Ic	55.4
IIa	55.6
IIb	56.1
IIc	55.2
IIIa	55.5
IIIb	51.8
IIIc	56.9

No attempt was made to sterilize the peaches. The series was run at 30° C. and the details of manipulation were the same as in the series

with cherries. The experiments extended from July 20 to July 26. They were run for eight periods (90.5 hours) in the respective gases and then they were all run in air for four periods (49 hours).

A summary of the results is given in Table 4. The general make-up of the table is the same as that of tables 2A and 2B. The results include the hourly rates of evolution of carbon dioxid per 100 grams of peaches and the ratios of anaerobic production to aerobic. The ratios as they appeared when the nitrogen and hydrogen were replaced by air are given also, in order to show the tendency toward a return to the normal.

In Table 4 is shown a different type of production of carbon dioxid from that shown in tables 2A and 2B. Here the effect of the absence of oxygen is manifested from the first in a greatly decreased production of carbon dioxid. The average ratio $\frac{An}{N}$ is less than .5. The amount and rate of production of carbon dioxid is approximately the same in both nitrogen and hydrogen. In air there is a steady decline for the first six periods, after which the hourly production remains almost constant. The point of constant production is reached about two or three periods earlier in nitrogen and hydrogen. This constant rate is less than half the rate during the first period.

After being kept for eight periods in nitrogen and hydrogen the peaches on being transferred to normal air did not regain the normal rate of production of carbon dioxid. The ratio $\frac{An}{N}$ was increased, however, from approximately .5 to .7.

These experiments show that the respiratory processes are very different in green fruits from those in ripe fruits. The former are dependent on an immediate supply of oxygen to the extent of fifty per cent of their activity. After four days in the absence of oxygen the tissue had been so injured that it was unable to return to its normal rate of respiration. There was a marked tendency to return, however, and this suggests that there is probably a point at which the return would be complete. It suggests further that growing tissues are able to continue their functions in the absence of oxygen for a time without injury.

At the close of the experiment the peaches were perfectly turgid. There were no visible signs of the growth of micro-organisms, and the regular rates of production of carbon dioxid preclude the possibility of their action to an appreciable extent. The flavor of the fruit was not noticeably different. At the time when the peaches were picked, an examination of the seed showed that there was a considerable quantity of endosperm surrounding the growing cotyledons and the testa was perfectly white. At the close of the experiment the testa was browned and the endosperm had disappeared. These effects were as noticeable in the peaches kept in air as in those kept in the other gases.

TABLE 4. AVERAGE HOURLY PRODUCTION OF CARBON DIOXID IN MILLIGRAMS PER 100 GRAMS OF GREEN PEACHES IN A CONTINUOUS CURRENT OF AIR, OF NITROGEN, AND OF HYDROGEN AT 30° C.

	In the respective gases									All in air					Average for all periods
Periods	1	2	3	4	5	6	7	8	Average	9	10	11	12	Average	
	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period	7.0	10.5	12.5	13.5	10.0	14.5	8.5	14.0	*90.5	12.0	12.0	11.5	13.5	*49.0	*139.5
Groups in air	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
Ia	24.7	18.7	13.6	12.3	11.6	9.4	9.9	8.8	12.9	7.8	9.4	8.8	13.0	9.9	11.8
Ib	25.8	18.0	13.9	10.5	9.9	7.3	8.3	7.9	11.8	6.7	8.0	6.8	8.3	7.4	10.3
Ic	27.6	21.7	14.6	14.0	12.7	13.3	11.5	13.0	15.4	10.0	12.6	13.1	13.4	12.3	14.3
Average	26.0	19.5	14.0	12.3	11.4	10.0	9.9	9.9	13.4	8.2	10.0	9.6	11.6	9.9	12.1
Groups in nitrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIa	14.0	9.8	6.1	6.1	7.1	4.9	6.0	6.8	7.2	6.2	9.8	7.7	6.8	8.0	7.3
IIb	13.2	8.3	7.5	4.8	4.3	3.6	4.8	4.7	6.0	5.0	6.5	6.7	6.6	6.2	6.1
IIc	14.2	9.6	7.3	6.4	4.1	2.9	3.2	4.7	6.1	4.9	8.1	7.1	7.0	6.8	6.4
Average	13.8	9.2	7.0	5.8	5.2	3.8	4.7	5.4	6.4	5.4	8.1	7.2	6.8	7.0	6.6
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$	.53	.47	.50	.47	.46	.38	.47	.55	.48	.66	.81	.75	.59	.71	.55
Groups in hydrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIIa	13.3	8.2	5.2	5.6	3.4	4.5	7.2	3.6	5.9	5.1	7.0	7.3	6.8	6.5	6.1
IIIb	14.3	8.5	6.3	5.4	4.4	3.9	7.2	4.5	6.2	3.0	8.4	9.2	9.7	7.2	6.7
IIIc	13.8	7.9	6.0	5.3	4.4	4.9	6.4	4.6	6.2	4.7	8.0	7.9	7.8	7.1	6.5
Average	13.8	8.2	5.8	5.4	4.1	4.4	6.9	4.2	6.1	4.3	7.8	8.1	8.1	6.9	6.4
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$	.53	.42	.41	.44	.36	.44	.70	.42	.46	.52	.78	.84	.70	.70	.53

* Total hours, not average.

Respiration of ripe grapes

From October 26 to October 30 an experiment was made with ripe Concord grapes. The experiment was the same in arrangement as those already described. The Concord grapes were bought at a grocery store, therefore their history is not known. They were in excellent condition. Each grape was carefully taken from the bunch by cutting its stem about three millimeters from the fruit. Only perfect berries were used and these were carefully chosen for uniformity. Twenty berries were used in each case. They were immersed in 95-per-cent alcohol, then rinsed in sterile water and placed in the sterilized respiration chambers. The grapes were kept at 30° C.

From November 8 to November 10 an experiment was conducted with Catawba grapes. It was identical in method with the experiment with Concord grapes, except that the temperature used was 37° C.

The weights of the several groups of twenty Concord grapes used and the weights of the groups of Catawba grapes are given in Table 5. In Table 6 are given the data obtained from the Concords and from the Catawbas.

TABLE 5. WEIGHT OF THE TWENTY GRAPES IN EACH RESPIRATION CHAMBER

Concord grapes		Catawba grapes	
Groups	Grams	Groups	Grams
Ia	52.5	Ia	47.1
Ib	48.4	Ib	48.7
Ic	50.4	Ic	47.5
IIa	48.8	IIa	50.5
IIb	49.7	IIb	45.2
IIc	49.3	IIc	43.8
IIIa	44.8	IIIa	47.4
IIIb	55.2	IIIb	42.8
IIIc	51.3	IIIc	47.5

It will be seen in Table 5 that the weights of the several groups of twenty grapes varied considerably from the 50-gram average, as did the weights of the groups of cherries.

From Table 6 it is clear that ripe grapes respire as rapidly in both nitrogen and hydrogen as in air. This was true of both Concords and Catawbas, in the experiment here described. It was true of the former at 30° C. and the latter at 37° C., and the higher temperature gave an increase in the rate of evolution of carbon dioxid quite in accord with the

TABLE 6. AVERAGE HOURLY PRODUCTION OF CARBON DIOXID IN MILLIGRAMS PER 100 GRAMS OF RIPE GRAPES IN A CONTINUOUS CURRENT OF AIR, OF NITROGEN, AND OF HYDROGEN

	Concord grapes at 30° C.										Catawba grapes at 37° C.			
Periods	1	2	3	4	5	6	7	8	9	Average	1	2	3	Average
	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period	10.0	21.0	10.5	13.5	10.5	14.5	9.5	13.5	11.5	*114.5	11.5	10.0	12.5	*34.0
Groups in air	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
Ia	8.9	4.1	4.8	4.8	5.5	4.9	4.2	3.9	5.8	5.1	11.0	9.3	8.3	9.5
Ib	9.8	4.5	4.7	4.9	4.9	4.9	4.3	3.7	5.6	5.1	11.7	9.5	8.9	10.0
Ic	10.8	Lost	3.7	5.9	5.3	3.7	4.9	4.8	6.4	5.5	11.2	9.0	10.5	10.3
Average	9.8	4.3	4.4	5.2	5.2	4.5	4.5	4.1	5.9	5.2	11.3	9.3	9.2	9.9
Groups in nitrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIa	10.1	5.2	5.5	7.2	4.4	4.3	5.0	4.1	5.4	5.5	9.1	8.8	5.4	7.7
IIb	Lost	Lost	5.7	Lost	Lost	3.5	3.2	3.2	3.9	......	9.3	Lost	Lost	Lost
IIc	10.9	5.1	Lost	7.3	6.1	7.3	6.3	5.4	7.3	6.9	12.1	12.3	9.7	11.3
Average	10.5	5.1	5.6	7.2	5.2	5.0	4.8	4.2	5.5	6.2	10.2	10.5	7.6	9.5
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$	1.07	1.19	1.27	1.38	1.00	1.11	1.07	1.02	.93	1.19	.90	1.14	.83	.96
Groups in hydrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIIa	10.8	5.5	7.2	6.8	6.2	8.1	6.9	6.4	9.4	7.3	10.8	10.6	9.2	10.1
IIIb	9.8	6.0	8.1	8.7	7.5	7.3	8.4	6.5	6.1	7.4	13.4	Lost	7.8	10.5
IIIc	Lost	4.6	6.5	5.9	7.0	6.2	8.0	6.2	5.5	7.1	11.3	10.8	8.4	10.1
Average	10.3	5.4	7.3	7.1	6.9	7.2	7.8	6.4	7.0	7.3	11.8	10.7	8.5	10.2
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$	1.05	1.26	1.66	1.37	1.33	1.60	1.73	1.56	1.19	1.40	1.04	1.15	.9[illegible]	1.03

* Total hours, not average.

Van't Hoff-Arrhenius law, if we assume that the two varieties would respire similarly under the same conditions. It will be further noted in Table 6 that in the case of the Concord grapes the respiration in the first period is nearly double that of some of the succeeding periods and after the first period the rate is almost constant throughout the succeeding periods. The increased evolution during the first period is possibly due to the release of carbon dioxid on the transference of the groups from a condition of room temperature to that of the experiment, since carbon dioxid has a lesser solubility in the cell sap at the higher temperature.

When the rates of evolution of carbon dioxid in grapes are compared with those in cherries it will be noticed that the cherries respire markedly faster per unit weight than do the grapes. This suggests that the rate of evolution of carbon dioxid is more or less proportional to the rate of spoiling of ripe fruit, since cherries spoil more quickly at the same temperature than do grapes. And since these processes seem to be quite independent of oxygen, they are probably mostly enzymatic, and hence the rate at which fruit spoils is more or less proportional to its enzyme content. This suggests that if the factors controlling the production of enzymes in fruits were sufficiently understood, these factors might be artificially controlled at a low enough cost to effect a great saving in the handling and storing of fruit. Such control would also materially prolong the fruit season.

Respiration of germinating wheat

From November 27 to December 1 an experiment was conducted with wheat. The wheat was soaked for twenty-four hours. It was then sterilized by immersion in 95-per-cent alcohol, and was rinsed in sterilized distilled water. Fifty grams of wheat were put into each respiration chamber and the methods were as before. A summary of the results is given in Table 7. The temperature during this experiment was 25° C.

From December 2 to December 6 a similar experiment was made with germinating wheat. The methods were the same as in the preceding experiment, except that the wheat was sterilized in a solution of formalin, 1 part to 600 parts of water, for 15 minutes, instead of being immersed in alcohol. The results are given in Table 8 (A). In Table 8 (B) are given the results of a set treated exactly as those in 8 (A) except that the respiration chambers were closed tightly with pinchcocks after being set up and were allowed to stand for seven days, at the end of which time the CO_2 was drawn off and measured.

It will be seen in tables 7 and 8 that respiration is much slower in hydrogen and nitrogen than in air. The rate of respiration of seeds sterilized in formalin was greater than the rate of respiration of seeds sterilized in alcohol. This increased rate obtains only in the continuous

TABLE 7. HOURLY AVERAGE PRODUCTION OF CARBON DIOXID IN MILLIGRAMS PER 100 GRAMS OF WHEAT IN A CONTINUOUS CURRENT OF AIR, OF NITROGEN, AND OF HYDROGEN AT 25° C. SEED STERILIZED IN 95-PER-CENT ALCOHOL

Period	1	2	3	4	5	6	7	Average
	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours
Duration of period.	11.5	12.0	10.0	11.0	14.0	9.0	14.0	*81.5
Groups in air	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
Ia..............	16.2	12.9	17.6	13.3	9.4	4.0	7.1	11.4
Ib..............	17.1	14.1	14.4	13.4	8.9	6.9	6.2	11.4
Ic..............	17.7	18.4	17.9	16.6	12.3	16.2	13.2	15.6
Average......	17.0	15.1	16.6	14.4	10.2	9.0	8.8	12.8
Groups in nitrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIa..............	8.2	6.7	8.5	6.2	3.9	4.5	3.1	5.7
IIb..............	9.4	7.9	5.8	6.1	5.9	4.4	3.5	6.1
IIc..............	9.8	7.8	6.9	6.6	5.3	3.8	3.4	6.2
Average......	9.1	7.5	7.1	6.3	5.0	4.2	3.3	6.0
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$..................	.54	.50	.43	.44	.49	.47	.37	.47
Groups in hydrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour
IIIa..............	11.0	8.8	6.8	5.8	5.0	4.5	4.0	6.5
IIIb..............	10.9	9.4	6.2	6.0	4.2	6.0	4.1	6.6
IIIc..............	8.9	9.5	6.6	6.1	5.2	5.2	3.9	6.4
Average......	10.3	9.2	6.5	6.0	4.8	5.2	4.0	6.5
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
$\frac{An}{N}$..................	.61	.61	.39	.42	.47	.58	.45	.51

* Total hours, not average.

streams of air and of nitrogen. In the hydrogen the rate of respiration of formalin-sterilized seed and of alcohol-sterilized seed was approximately the same. This is suggestive of the work of Nabokich (1903), who found that sterilization of seeds by chemicals such as mercuric chlorid ($HgCl_2$) resulted in an increased rate of production of carbon dioxid which may continue for two or three days. The increased production of carbon dioxid in air and in nitrogen shown in Table 8 over that shown in Table 7

(1903) Nabokich, A. J. Über den Einfluss der Sterilisation der Samen auf die Atmung. Ber. d. deut. bot. Gesell. 21: 279-291.

was not due to contamination, since wheat that had been killed by boiling and then sterilized the same as the others, when kept in a continuous current of air showed no noticeable production of carbon dioxid during the interval of these experiments. Contamination at once manifests itself by a very marked increase in the rate of evolution of carbon dioxid. These experiments indicate, then, either that alcohol reduces the production of carbon dioxid or that formalin stimulates it. If the alcohol is injurious the effect is purely local, for the wheat in air germinated and grew rapidly. Since the seeds were rinsed in three different vessels of sterile water, the alcohol or formalin contained would be very slight, for the interval of sterilization in alcohol was only a second and in formalin only fifteen minutes.

TABLE 8. AVERAGE HOURLY PRODUCTION OF CARBON DIOXID IN MILLIGRAMS PER 100 GRAMS OF WHEAT IN AIR, NITROGEN, AND HYDROGEN AT 25° C. SEED STERILIZED IN FORMALIN

	A. In continuous current of respective gases									B. Left in respective gases for seven days. No current
Period	1	2	3	4	5	6	7	Average	Total carbon dioxid produced per 100 grams of wheat (in milligrams)	Total carbon dioxid produced per 100 grams of wheat (in milligrams)
	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours		
Duration of period....	11.00	10.00	14.00	11.50	14.75	7.50	14.75	*83.50		
Groups in air	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour		
Ia.......	23.0	26.8	33.4	41.9	30.9	28.1	34.5	31.6	2,640.8	449.0
Ib.......	18.8	27.7	43.0	45.6	30.1	29.2	29.0	32.4	2,703.4	378.4
Ic.......	20.4	34.2	45.8	49.5	31.4	31.4	37.1	36.6	3,054.6	360.8
Average.	20.7	29.6	40.7	45.7	30.8	29.6	33.5	33.5	....	396.1
Groups in nitrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour		
IIa.......	17.1	8.1	9.1	10.6	8.2	6.7	7.2	9.5	796.0	414.6
IIb.......	8.0	7.5	5.6	5.3	7.8	6.1	5.4	6.5	543.8	363.8
IIc.......	7.7	9.1	9.1	9.6	4.8	7.7	5.5	7.4	617.4	348.2
Average.	10.9	8.2	7.9	8.5	6.9	6.8	6.0	7.8	....	375.5
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio		
$\frac{An}{N}$........	.53	.28	.19	.19	.22	.23	.18	.23		
Groups in hydrogen	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour	Mg. per hour		
IIIa.......	3.5	6.0	6.4	8.4	4.5	4.8	3.7	5.3	444.2	425.2
IIIb.......	6.6	7.9	9.9	8.9	7.2	7.2	5.3	7.6	633.4	452.8
IIIc.......	6.8	6.6	7.1	6.5	4.4	6.1	7.0	6.3	525.0	463.6
Average.	5.6	6.8	7.8	7.9	5.4	6.0	5.3	6.4	....	447.2
	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio		
$\frac{An}{N}$........	.27	.23	.19	.17	.18	.20	.16	.19		

* Total hours, not average.

The decrease in respiration in a continuous current of hydrogen and of nitrogen below that in a continuous current of air was about 50 per cent in seeds sterilized in alcohol and about 80 per cent in seeds sterilized in formalin. In these tissues containing actively growing protoplasm, the absence of oxygen results in a marked decrease in the respiratory rate. The same was shown also with green peaches (Table 4), in which the decrease was about 50 per cent. On the other hand, the series with cherries, blackberries, and grapes indicate that in tissue which is mature and not in an actively growing condition, such as the pulp of ripe fruits, the oxygen relation is very different from that in actively growing tissues and the respiratory rate is little affected by it. There seems to be in fruits a direct relationship between protoplasmic activity and the effect of oxygen in the production of carbon dioxid.

Although oxygen does not appear to directly affect the production of carbon dioxid in ripe fruits, it does greatly affect other metabolic activities, as is shown later in this bulletin.

The rate of anaerobic respiration of germinating wheat at 25° C. is about the same as that of grapes and green peaches at 30° C., but it is considerably less than that of cherries at 20° C. The rate of normal respiration is slightly slower for wheat seed sterilized in alcohol than the rate for green peaches, but it is considerably faster in the case of wheat seed sterilized in formalin.

In the light of the literature of this subject, these experiments seem to show that the production of carbon dioxid in anaerobic respiration is due to agents, probably enzymes, which work independently of oxygen, and that these are practically the only carbon-dioxid-producing agents in ripe fruits. On the other hand, in tissues containing actively growing protoplasm the production of carbon dioxid seems to be due as much to processes that are dependent on oxygen as to those independent of that gas. The latter processes may be enzymatic, but it is probable that the direct metabolism of the living protoplasm itself plays a considerable part in them.

METABOLISM AND KEEPING QUALITY OF FRUITS IN NITROGEN, HYDROGEN, CARBON DIOXID, AND AIR

Red Astrachan apples and Wiggins, Late Crawford, Crosby, and Elberta peaches were used in these experiments. Sound, carefully chosen fruits were placed in large sterilized glass jars of four liters capacity. Bottles containing sulfuric acid (H_2SO_4) and potassium hydroxid (KOH) were placed in the jars in order to prevent the accumulation of moisture and carbon dioxid. The apples were dipped in 95-per-cent alcohol and then rinsed in sterile water before being placed in the jars, so as to render them as nearly sterile as possible. No attempt was made to sterilize the peaches.

The jars were filled with the respective gases and all except those containing air were sealed. The jars containing air were plugged with cotton stoppers.

The fruits were left in these jars for several days at laboratory temperature, which ran from 21° to 23° C. Notes were taken from time to time as to the general appearance of the fruit. When the jars were opened, notes were made of the color, texture of skin and flesh, flavor, and other characters.

Behavior of Red Astrachan apples in air, nitrogen, and hydrogen

Seven apples were placed in each jar. The apples in each jar were as nearly like those in the other jars as careful selection could make them. In each jar some apples were fairly ripe and these graded back to some that were rather green. The experiment lasted from August 5 to August 18, 1911.

Jar I was in air; jars IIa and IIb were in nitrogen; jars IIIa and IIIb were in hydrogen.

After four or five days the apples in nitrogen and those in hydrogen began to have a bleached appearance. The red color then gradually disappeared. Finally the apples acquired a brownish tinge. The apples in air remained a beautiful red.

When the jars were opened the apples in air had a fine apple odor and the appearance of very ripe Astrachan apples. They were much less sour to the taste than when placed in the jar. No soft rots had developed, but two apples were nearly destroyed by what appeared to be brown rot. The other apples were in good condition.

The apples in both nitrogen and hydrogen looked as if they had been about half baked in an oven with a slow fire. They had entirely lost their red color. The skin in places was elevated in small blisters. The flesh was light brown at the surface and white inside, but when exposed to the air it browned very rapidly — many times more rapidly than did the flesh of the apples that had been kept in air. The apples had no bad flavor. The taste was that of half-baked apples, according to five persons who tasted them. The " baking " was greatest near the surface and gradually lessened toward the core. The natural flavor was almost entirely gone.

In order to learn whether the browning and the apparent baking were due to some organism, sterile agar tubes were inoculated with pieces of the browned flesh taken from both the nitrogen and the hydrogen series. No growth developed from them at all, showing that these effects were the result of anaerobic metabolism of the fruits themselves. Some agar tubes were inoculated with the rotted tissue from one of the apples in the air series and an abundant growth of a mold resulted.

This series of experiments shows that apples need aeration and that they cannot be satisfactorily held in inert gases such as nitrogen and hydrogen.

Behavior of Wiggins peaches in air, nitrogen, hydrogen, and carbon dioxid

The peaches were large and market-ripe. They had white flesh and some were beginning to show a light red blush. They were all hard. The surface of peaches is such that it was deemed inadvisable to attempt to sterilize them. They were chosen for uniformity. Ten peaches were placed in each sterile jar. The treatment was the same as with the apples. The experiment was begun on August 19, 1911.

Jars Ia and Ib were in air with potassium hydroxid (KOH) and sulfuric acid (H_2SO_4) as absorbents; jars IIa and IIb were in nitrogen and jars IIIa and IIIb in hydrogen with the same absorbents; and jars IVa and IVb were in carbon dioxid with sulfuric acid (H_2SO_4) as the only absorbent.

Seven days after the experiment was begun, jars Ia, Ib, IIa, IIIa, and IVa were opened and examined. There were only three peaches in jars Ia and Ib that had not rotted. The three good peaches were of a beautiful cream color. The flesh was juicy and soft and of excellent flavor. The peaches contained no more red, however, than at the beginning. The rotted peaches were covered with molds, brown rot being the chief one.

No molds could be found in jar IIa, IIIa, or IVa, and the peaches looked about as they did when placed in the jars. They had acquired a bad flavor, however, just strong enough to spoil them for eating purposes. When they came in contact with the air they darkened somewhat rapidly. The epidermis, however, retained its green color for some time.

Jars IIb, IIIb, and IVb were kept in their respective gases for three weeks longer. At the end of that time the peaches in nitrogen and those in hydrogen were mostly brown and soft. The peach aroma and flavor were entirely gone. There were some hard green spots on some of the peaches and these had a decidedly bad flavor. The soft brown parts had a snappy alcohol flavor and persons who were unacquainted with the treatment that they had received pronounced them brandied peaches. This flavor was not particularly unpleasant.

The peaches in carbon dioxid were mostly green and as hard as when placed in the jar four weeks earlier. The flavor was very bad. It was not the snappy alcohol flavor of the peaches kept in nitrogen, but was bitter and nauseating. The hard green spots that were noted on the peaches in nitrogen and in hydrogen also had this flavor, but it was not so strong in them. When the peaches from the jar of carbon dioxid were placed in air they turned brown very rapidly, but they did not soften markedly.

It seems to be evident that carbon dioxid considerably decreases the hydrolysis of pectose, since peaches in that gas did not soften. In this case, as with the apples, the need for good aeration is apparent, since the

flavor was spoiled in the gases containing no oxygen and since in a closed space without ventilation the carbon dioxid resulting from the respiration of the fruit accumulates so rapidly as to displace the air in a short time.

Behavior of green, market-ripe, and ripe peaches in air, nitrogen, hydrogen, and carbon dioxid

In order to determine the effect of the degree of ripeness on the rate of softening of peaches, some very ripe Elbertas, some market-ripe Crosbys and Late Crawfords, and some hard green Crosbys were treated in the same way as were the Wiggins peaches and were allowed to remain in the gases for two weeks. The experiment was begun on September 20. The peaches in air retained their qualities and ripened well, but the ripe Elbertas and some of the others deteriorated from brown rot after a few days.

At the end of the two weeks the ripe Elbertas, which were soft at the beginning, had a very bad flavor in carbon dioxid and almost as bad a flavor in nitrogen and in hydrogen. They had darkened noticeably. As soon as they were taken out into the air they darkened rapidly under the skins and had the appearance of peaches that had been badly injured in shipment in refrigerator cars.

The market-ripe Crosbys and Late Crawfords softened somewhat, but not so much as in air. Their flavor was very bad and they showed browning, which increased very rapidly when they were placed in air. The hard Crosby peaches remained hard in all three of the oxygen-free gases.

DISCUSSION

Since fruits produce carbon dioxid very rapidly, as has been shown, and since they brown and lose their flavor when they are not supplied with oxygen, the need for thorough ventilation becomes apparent. The peaches that were described at the beginning of this bulletin as having been injured by " ice-scald " had each been wrapped separately in paper. With respiration as rapid as it has been shown to be, it is a matter of only a few hours until all the air within the paper wrapper would be displaced by the carbon dioxid given off by the peach. From the experiments described, it is quite probable that " ice-scald " is injury due to poor aeration and to an accumulation of carbon dioxid.

Certain packing companies provided with refrigerator cars have appreciated this need of plant tissues for fresh air and have conducted some experiments in the ventilation of their cars in transit. They have obtained some very satisfactory results with several kinds of fruits and vegetables. The results have been so satisfactory that one large packing company is putting a special ventilator, which can be opened or closed as

the shipper prefers, over the doors of its refrigerator cars. When the car is moving, air will be drawn out through these ventilators and will be replaced by fresh air that has been cooled in its passage through the ice bunkers at each end of the car.

The question of wrappers for fruits is worthy of an extended investigation from the standpoint of ventilation. The good points in favor of a separate wrapper for peaches, apples, and other fruits are numerous. But such wrappers allow only a very small air space around each fruit. Some type of perforated or porous wrappers has been suggested as a possible means of combining the desirable qualities of the wrappers with better ventilation of the fruit.

It seems that to some extent peaches can be prevented from softening by inert gases, and especially by carbon dioxid; this is of no economic value, however, until some method can be found by which the softening will be prevented and in the use of which the flavor will be retained.

Preliminary experiments for an extended study of the relations between carbon dioxid and oxygen in fruits, vegetables, and other plant tissues have been made by the writer, and he is hoping to continue this work, particularly in its relation to various temperatures, during the coming season.

SUMMARY

1. The respiration of ripe fruits, as well as that of green fruits, is rapid.

2. The anaerobic production of carbon dioxid by ripe cherries, blackberries, and grapes is as rapid as the aerobic production for a considerable length of time.

3. Ripe fruits that spoil quickly, such as cherries, have a higher respiratory rate than those that do not spoil so quickly, such as grapes. This is due possibly to a higher enzyme content.

4. Fruit tissues that respire as actively anaerobically as aerobically seem to be those that have finished their growth and are ripe.

5. Growing tissues, such as green peaches and germinating wheat, respire more than twice as rapidly aerobically as anaerobically. The activity of the protoplasm would seem to be connected with this more direct use of oxygen in the production of carbon dioxid.

6. If growing tissues, such as green peaches, are placed in an oxygen-free gas for a few days and then brought back into air, the rate of production of carbon dioxid does not entirely return to the normal. This would indicate a permanent injury to the protoplasm or to some of the enzymes, due to insufficient oxygen.

7. Ripe apples lose their color, texture, and flavor, and take on the qualities of half-baked apples, by being kept for a sufficient length of time in oxygen-free gases. This emphasizes the need of good aeration for apples.

8. The softening of peaches seems to be decreased greatly by carbon dioxid and to a considerable extent by hydrogen and nitrogen.

9. Peaches become brownish and acquire a very bad flavor when oxygen is withheld from them.

10. " Ice-scald " seems to be injury due to insufficient oxygen and to an accumulation of carbon dioxid within the paper wrappers in which peaches are so often shipped. With good ventilation in conjunction with good refrigeration, such injury may be greatly reduced. This applies to fruits in storage as well as to those in transit.

11. Good ventilation in conjunction with refrigeration is of prime importance for the successful storage of fruit.

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THE ASPARAGUS MINER AND THE TWELVE-SPOTTED ASPARAGUS BEETLE

Under the direction of

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THE ASPARAGUS MINER

(*Agromyza simplex* Loew)

Order, *Diptera* Family, *Agromyzidae*

D. E. Fink

The asparagus miner, although capable of doing considerable damage, has as yet attracted but little attention among growers of asparagus. The insect has been known to injure seedlings and newly set asparagus beds to such an extent as to lead growers to consider the advisability of plowing under an entire bed. Yet, even in localities where the miner occurs abundantly as a pest, few growers are at all familiar with the nature of its work. As a matter of fact, the injury caused by the miner has been attributed to a variety of causes and has been laid at the door of insects entirely innocent of this peculiar form of injury. Centipedes and wireworms, particularly the latter, have come in for their share of blame for injury to asparagus stalks. Some persons have attributed the early yellowing of the stalks and the wilting appearance of the plants to drought, little suspecting that the real cause was the asparagus miner.

As the life history of this pest has been but imperfectly worked out heretofore, the writer undertook to study the insect with the view of obtaining a more accurate knowledge of its habits and life history and at the same time of determining how it can best be controlled.

In taking up the study during the winter, various devices for breeding the insects were at first tried. It was necessary to have a breeding-cage that would allow close observation. The cage used consisted of an ordinary eight- or ten-inch flowerpot filled with soil, in which a clump of asparagus roots was set. A glass cylinder with a cheesecloth top stood on the flowerpot, thus allowing close observation to be made without disturbing the insects in the least.

The photographs shown in this bulletin were nearly all enlarged from negatives first obtained by the use of an ordinary upright camera. The negatives showing the egg, larva, pupa, and adult were placed in a horizontal camera used for making lantern slides. The bellows of this camera are arranged so that a subject can be either reduced or enlarged. A positive was first obtained, enlarged from the original negative; the positive was then used as the subject, from which an enlarged negative was made. [If a sharp negative is obtained in the first place, by this process one can enlarge the subject to any desired size.]

Note.—The writer is indebted to Professor Glenn W. Herrick for frequent advice and for many valuable suggestions in the preparation of this bulletin; and to the Department of Entomology at Cornell University for the use of the insectary for breeding purposes and for the use of the cameras, without which the work could scarcely have been done.

HISTORY AND DISTRIBUTION

The asparagus miner is a native American species and was first discovered by Loew* occurring in some of the Middle States — Pennsylvania, New Jersey, and New York. As the adult of the asparagus miner is a fly, it is likely to be confused with the asparagus fly of Europe, *Platyparea poeciloptera* Schrank. The asparagus fly, however, is a borer, not a miner. It bores within the stalks of the asparagus, making galleries, much as does any common borer. The asparagus miner, on the other hand, mines and eats out the parenchyma and chlorophyll between the outer epidermis and the bast wood of the stalk, never enters the heart wood, and differs greatly in general appearance from the asparagus fly.

Professor K. Sajo† mentions the presence of a fly on asparagus, identified by him as *Agromyza maura* Meig. He states that the body of the insect is two to two and one half millimeters long, and that the larva mines beneath the epidermis, gnawing out the chlorophyll and thus weakening the circulation in the plant. The pupa, he says, is easily found by pulling the stalks in winter. It is three to four millimeters long, dark brown, and resembles the "flaxseed" stage of the Hessian fly. These flies, he states, are widely distributed in central Hungary. It would appear from Professor Sajo's description of the habits of *Agromyza maura*, either that its work resembles closely that of *Agromyza simplex* and the insect is another species of the family *Agromyzidae* working on asparagus in Europe, or that it is the same species which is working in this country, namely, *Agromyza simplex* Loew.

Flies that issued from pupæ on asparagus stalks kept in cages were sent to A. L. Melanders of Pullman, Washington, for verification. Doctor Melanders was fairly certain that the flies were Loew's species, and gives the following characters distinguishing the two species: "*Agromyza simplex* has six frontal bristles, the orbital pubescence inconspicuous, usually four nearly uniform sternopleurals in the upper row, the tip of the clypeus is usually visible in profile view, the segments of the fifth vein equal, and the cross veins very close. *A. maura* has four frontals, denser orbital hairs, usually three unequal sternopleurals, face not projecting, segments of fifth vein 3/2, and cross veins more separated."

In this country the adults of the asparagus miner have been known to collectors for many years, in fact long before it was known on what food plant the insect thrives. The miner was first collected on asparagus plants by F. H. Chittenden of the Bureau of Entomology, United States Department of Agriculture, in 1897. Mr. Chittenden suggested that the insect perhaps fed on asparagus.‡ In 1896 F. A. Sirrine, of the New

* Berliner Entomologische Zeitschrift, vol. 13, p. 46. 1869.
† Prometheus, vol. 13, no. 650, pp. 403-404. 1902.
‡ Bul. 10, n. s., Div. Ent. U. S. Dept. Agr., pp. 54-62. 1898.

York (Geneva) Agricultural Experiment Station, found the puparia of flies buried beneath the epidermis of asparagus stalks. Sirrine subsequently obtained adults from these puparia and later worked out the life history of the insect, naming it the "asparagus miner."* In 1911 F. H. Chittenden issued a circular† wherein he traced the distribution of this pest in the United States. According to Chittenden the asparagus miner was first observed by him at Cabin John, Maryland, in 1897. Later, complaints of injuries were received from the District of Columbia and from Knoxville, Tennessee. Although the miner was observed by Sirrine in 1896, the notice to that effect did not appear until the publication of his bulletin in 1900. Reports were received in 1901 from the vicinity of Philadelphia, where the insect proved to be more destructive to asparagus than were the common asparagus beetles; here several beds of asparagus were destroyed by the miner. In the neighborhood of Concord, Massachusetts, where hundreds of acres are devoted to this crop, infestation was practically absolute, the insects being as abundant as the common asparagus beetle. In 1907 W. E. Britton reported the miner from Connecticut, where asparagus growing in the station grounds was found to be infested with the miner. Mr. Shamel later reported that he found infestation in every field visited in Massachusetts and Connecticut. In 1905 R. E. Smith‡ made the following statement regarding the miner: "This is another eastern asparagus insect which is becoming abundant in California and common throughout the State." In Bulletin 172 of the California station Mr. Smith says that "one noticeable feature of this year's growth has been the premature yellowing and dying of many stalks without regard to rust." In 1908 I. J. Condit reported the miner in the vicinity of Antioch, California, where this insect and the common asparagus beetle were equally abundant. Chittenden also observed the species well established on asparagus in the vicinity of Portsmouth, Virginia. In 1908 severe injury was again reported from Concord, Massachusetts. In 1911 the writer found the miner somewhat common on the agricultural college farm at Cornell University and in other localities in the vicinity of Ithaca, New York.

The asparagus miner is now known to be widely distributed in the eastern part of the United States, in fact wherever asparagus is grown to any considerable extent. The insect has been reported as having caused injury to asparagus in New York, New Jersey, Pennsylvania, Maryland, Connecticut, Massachusetts, Long Island, District of Columbia, Tennessee, Virginia, and throughout California.

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* Bul. 189, New York (Geneva) Agr. Exp. Sta., pp. 277–282. 1900.
† Cir. 135, n. s., Bur. Ent., U. S. Dept. Agr., pp. 1–5. 1911.
‡ Bul. 165, California Agr. Exp. Sta., p. 95. 1905.

INDICATION OF PRESENCE OF ASPARAGUS MINER

To the uninitiated and casual observer, the presence of the miner on asparagus is a matter of conjecture. While the injurious effect of beetles on asparagus is evident at once—their presence being betrayed by the bare branches and by the larvæ and adults on the stalks and branches—the miner, on the other hand, is a very inconspicuous insect. The only time when the observer is at all aware of its presence is when the adult flies are congregated on the stalks and branches. Since no injury is apparent as a result of the presence of these flies, however, they may easily be mistaken for visitors rather than recognized as pests. If a stalk that looks yellow at the base is pulled out, it will be found that the skin peels off very easily or is cracked; and if the observer traces some of the mines he will find in most cases a white maggot beneath the epidermis of the stalk.

This yellowing of the stalk at the base, or shriveled appearance and premature yellowing of the entire plant, is a sure indication that the asparagus miner is present. In cutting beds this is not evident until late summer, but seedling beds are injured early in the summer. When badly infested a bed assumes throughout the appearance of suffering from severe drought. The plants appear yellowish and sick, the stalks begin to shrivel and die. This condition prevents the roots from becoming as fully developed as they should be, and as a result the entire bed is ruined.

NATURE AND EXTENT OF INJURY

The injury to asparagus stalks is done by the maggot, the little worm that mines at the base of the plants just beneath the epidermis. The mines begin at or near the surface of the soil and extend upward for a foot or more, assuming a zigzag appearance as the larvæ wind their way upward. When several larvæ are working on one stalk, as is usually the case, the mines soon begin to merge and the entire base of the stalk becomes girdled. Indeed, on examination of over eighty stalks, the writer found at least three puparia on every stalk and as many as twelve on some stalks. Chittenden reported finding " the puparia in great numbers underneath the outer skin of the root, and as many as nine were counted in a space only an inch long on one stalk." The tissues between the outer epidermis and the bast wood are eaten out by the maggot and as a result the outer skin becomes dry and yellowish and shrivels up, eventually causing the stalks to wilt and die. W. E. Britton states that " nearly every stem examined showed the tunnels, and on the station grounds the plants which first turned yellow and died were those most seriously attacked by the miner." R. E. Smith states that in some instances the

asparagus miner was very abundant in the stems of the yellow stalks. The mines extend for a considerable distance below the surface of the soil. Stalks cut as close as possible to the crown have failed to show mines extending quite to the crown; nevertheless, Chittenden found plants that showed injury seven inches below the surface of the soil, and on some plants the puparia were found in great numbers underneath the outer skin of the roots. This instance of an attack on the roots undoubtedly places the miner as a pest to be contended with.

As soon as the adults appear in spring they begin to lay eggs on volunteer plants or seedling beds. The adults make no attempt to oviposit on cutting beds, and it is because of their instinct in not ovipositing on cutting beds that the early attack on seedling plants and on plants that are newly set out becomes very severe.

DESCRIPTION OF STAGES

The adult

The adult is a metallic black fly of glistening appearance, not more than three or four millimeters, or about one sixth of an inch, in length, with a wing expanse of five or six millimeters, or about one fifth of an inch. The males are somewhat smaller than the females, with a more or less triangularly shaped abdomen. One of the striking features in the adult is a picture of a face on the thorax (Fig. 127). The following is a technical description of the adult by Loew:* "Head unicolor, feet and halteres unicolor, discal cells short, length of body one and one twelfth lines, wing one and one sixth lines. Shining black head entirely concolor, front is holosericeous (covered with minute shiny silk hairs), ocellar triangle shining. Lateral margins subshining, abdomen rather broad, very shiny. Feet and halteres wholly black, costal veins from apex of first vein thickened, discal cells short, so that the two ultimate segments of fifth vein are equal, transverse veins approximated, posterior ones oblique."

The egg

When first laid, the egg is glistening white in color and measures five tenths of a millimeter in length and a little over one tenth (.12) of a millimeter in width. The egg is elongate oval, slightly wider at one end and more or less pointed at the other. There are no markings nor sculpture on the outside of the egg and the eggshell is at first viscid and transparent, so that the embryo is clearly visible through the shell.

The larva

Pure white when first hatched, the maggot becomes cream-white when fully grown, measuring four to five millimeters in length. It is long,

* Berliner Entomologische Zeitschrift, vol. 13, p. 46. 1869.

round, about five times longer than wide, of nearly uniform diameter but narrowing slightly toward either end. The head bears a black rasping jaw with one large tooth and two to three small teeth. The movement of this jaw is effected by muscles attached to a muscular framework. Between the head and the first thoracic segment on the dorsal surface arises a pair of spiracles, borne on two stalks. From the anal segment two stalks are prolonged caudad, and bear two anal spiracles. Both pairs of spiracles are black, and with the black jaw they form the only contrast to the otherwise white body.

The puparium

When first formed the puparium is light brown; later it becomes dark brown. It is flat and has been compared to the "flaxseed" stage of the Hessian fly. It is about four or five millimeters long. A pair of hooks is borne at each end of the puparium, by means of which it attaches itself firmly beneath the epidermis of the asparagus stalk (Fig. 132).

LIFE HISTORY AND HABITS

In the observations made in 1912 in the vicinity of Ithaca, New York, the adults began to issue forth on May 26 and afterwards. As the season that year was rather late and cold, it is possible that the adults normally issue about the middle of May. The males appear first, several days before the females. Copulation usually begins within two or three days after the females appear; in breeding cages kept outdoors in these experiments, copulation began on the second day after the emergence of the females. Within twenty-four to thirty-six hours, or one to two days, after copulation, oviposition by the females begins.

Where oviposition takes place

Before beginning to oviposit the female is usually seen running up and down an asparagus stalk, searching with her proboscis for a suitable place in which to lay her eggs. After this preliminary test of the entire stalk the female usually begins to oviposit at the base of the stalk at or near the surface of the soil; sometimes, according to the writer's observations, if the soil around the base of the stalk is loose the female even ventures below the surface as far as possible. She then takes up a position with her body parallel to the long axis of the stalk, and, bending her abdomen at almost a right angle to the stalk, begins to work her ovipositor into the epidermis. The ovipositor eventually pierces the epidermis and the egg is inserted just beneath it. The process of probing the stalk is repeated after each egg is deposited. The writer has observed a female performing

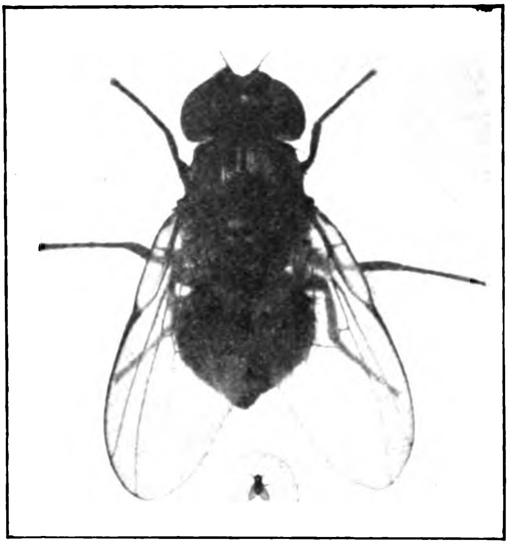

FIG. 127.— *Asparagus miner; fly, enlarged and natural size*

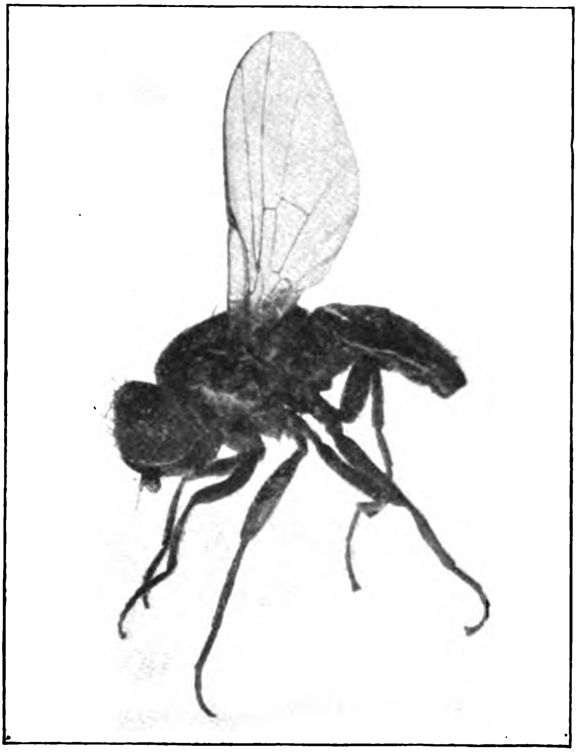

FIG. 128.— *Asparagus miner; fly, side view, much enlarged*

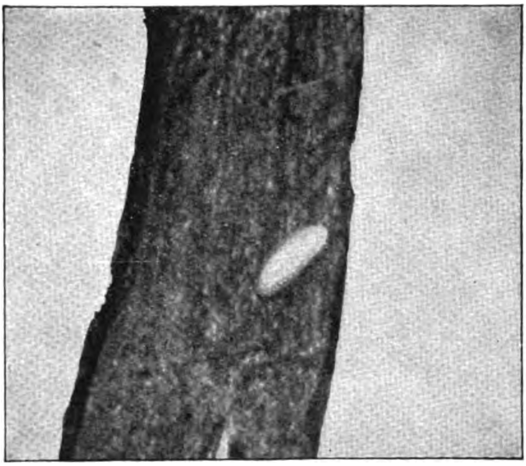

FIG. 129.— *Egg of asparagus miner*

FIG. 130.— *Larva of miner, enlarged*

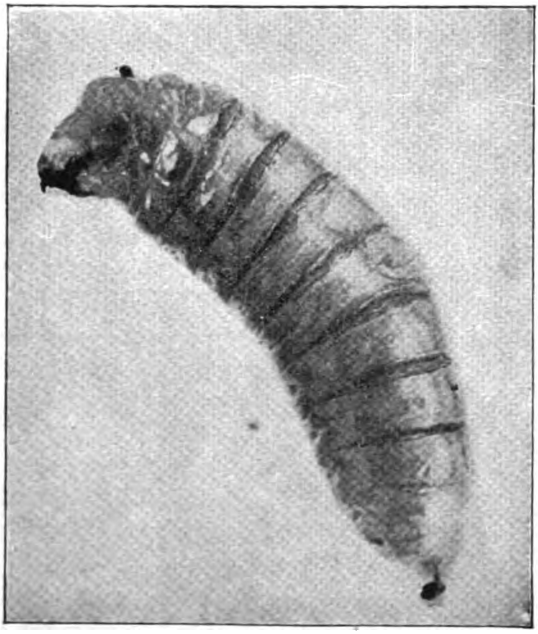

FIG. 131.— *Larva of miner, much enlarged*

FIG. 132.— *Puparium of asparagus miner*

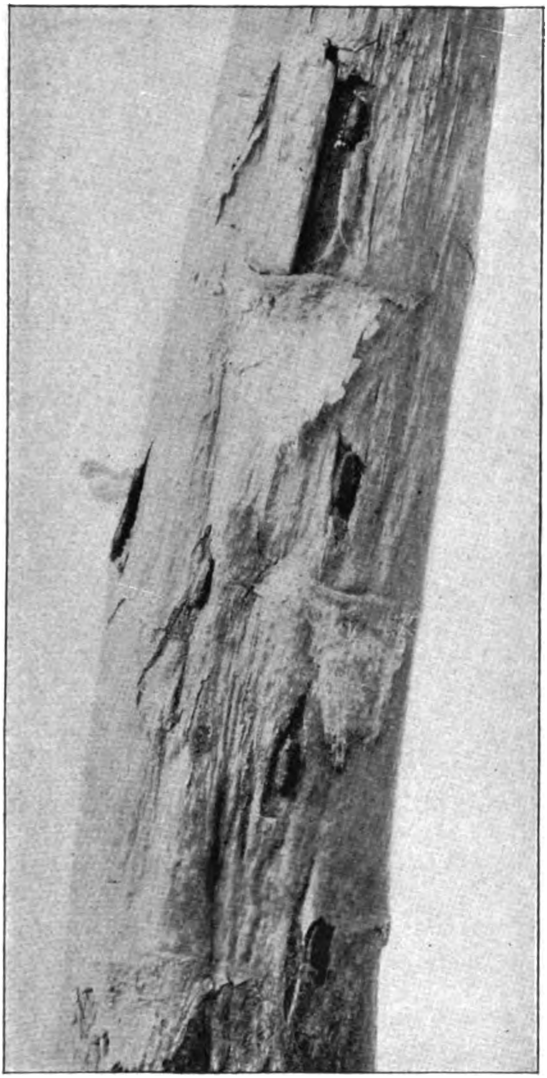

FIG. 133.— *Puparia in crevices in asparagus stalks*

FIG. 134.— *The mine of a larva in stalk of asparagus*

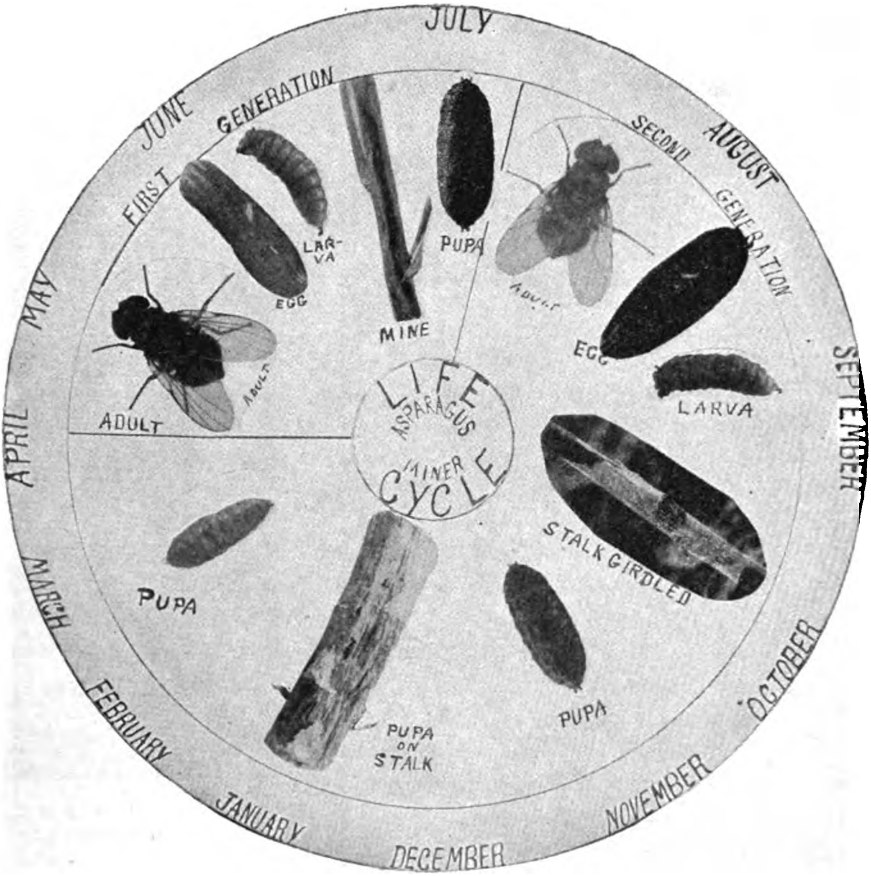

FIG. 135.— *Life cycle of the asparagus miner*

the above evolutions for over an hour, during which time at least nine eggs were inserted.

On the outside of the stalks there are no indications that eggs have been deposited. It is probably for this reason that the eggs of the miner have never before been observed. Unless one actually sees the female ovipositing, the finding of the eggs, as the writer had occasion to learn, becomes a difficult task. If a stalk on which oviposition has been observed is pulled out and examined carefully with a hand lens, all that can be seen are tiny punctures leading to raised areas. If the epidermis is carefully peeled from these raised areas, the egg will usually be found adhering either to the peeled epidermis or to the tissues of the stalk under the epidermis. Sometimes, however, when the stalk is old and the female is unable to work her ovipositor under the epidermis, part of the egg may remain protruding from the epidermis. In these experiments eggs thus inserted were never observed to hatch.

Incubation of egg

Beginning with the egg the entire life cycle of the asparagus miner, with the exception of the adult stage, is passed in concealment beneath the epidermis of the asparagus stalks. The eggs incubate for twelve to eighteen days, approximately, and the first indication of hatching is the beginning of a mine.

Habits of the larvæ

The larvæ begin to mine their way up the stalk as soon as they emerge from the eggshell. They may mine for a foot or more above the surface of the soil and then mine downward again, thus producing zigzag mines. When several larvæ are working on a stalk, as is usually the case, the stalk eventually becomes completely girdled. When nearly full-grown the larvæ direct their mines downward, and later continue to mine below the surface of the soil, so that when they finally become full-grown they can pupate below the surface of the soil where they are kept moist. During the summer, however, the larvæ may pupate anywhere along the stalks, above or below the surface of the soil. The depth varies at which they pupate below the surface of the soil. Observations made to determine this point indicate a variation from half an inch to six or seven inches below the soil surface. This is rather important, since the methods of control of the pest, thus far, seem to depend on the effectiveness with which the puparia are destroyed.

The puparium

Within the last larval skin the larva transforms into a brown, somewhat flat, segmented-appearing puparium, in which condition the resting stage is spent. The puparia are found in the mines where the larvæ have stopped

feeding. During the transformation of the larvæ into pupæ the two pairs of spiracles, which are somewhat prominent in the larval condition, are transformed into the two pairs of prominent hooks that are so characteristic of the puparia. These hooks serve to keep the puparia in position beneath the epidermis and undoubtedly prevent them from being shaken loose even when the stalks are pulled away from the plants.

The insects remain in the pupal state for two to three weeks before the new generation appears. The puparia formed during the fall are carried over on the stalks to the next spring. It is this fall brood of puparia that asparagus-growers are urged to destroy, thus preventing the appearance of the adults and their consequent egg-laying in the following spring.

Seasonal summary of life history

The adults appear from the middle to the last of May, and within a week after their appearance eggs are deposited on seedling stalks and on volunteer plants. This takes place from about the end of May to the first week of June. Within two to three weeks, or about the middle of June, the eggs hatch and the larvæ begin to mine the stalks. The larvæ attain full growth by the end of June to the first week in July and pupate beneath the epidermis of the stalks. Thus, larvæ attaining their full growth pupated on July 3, and the adults began to issue forth on July 20 and afterwards. Pupation, therefore, lasts for seventeen to twenty-one days. The adults of the new generation soon begin to oviposit and the life cycle is repeated. The larvæ of the new generation attain their full growth by the end of August to the first week in September. The puparia formed remain over winter, the adults not appearing before May of the following year. There are, therefore, two generations a year in the vicinity of Ithaca, New York.

METHODS OF CONTROL

Owing to the habits and natural history of the asparagus miner, the use of insecticides for its control has not been experimented with by other workers. Chittenden suggests permitting a few volunteer plants to grow during the cutting season in order to lure the insects to deposit their eggs on them, these plants being later pulled and burned. This method, however, does not take into consideration the presence of seedling beds, which cannot be pulled and which offer a place for the fly to deposit her eggs. Sirrine suggests pulling the stalks of a badly infested bed late in the fall and thus destroying the puparia. Where the stalks can be pulled easily this is undoubtedly the best method to pursue; but in a number of instances in the experiments in the fall of 1912 the writer found that not only were the stalks hard to pull out, but also they required the aid of a

good jackknife for cutting them loose. Early in spring, however, if the soil is worked loose about the asparagus clumps to a depth of three inches or more, the stalks are pulled out easily without the least danger of scattering the puparia.

Several experiments were conducted by the writer during the summer of 1912 with sprays for killing both the larvæ and the flies.

Experiments for control of the larvæ

Two experiments were made for killing the larvæ. The first consisted of the use of "Black-leaf 40" tobacco extract at the rate of 1 to 700, four pounds of soap being added as a sticker. In the second experiment "Black-leaf 40" was used at the rate of 1 to 500, with four pounds of soap added as a sticker. In both the experiments the primary object was to spray the stalks of plants badly infested with the miner and to determine whether the given solutions would eventually have any effect on the maggots beneath the epidermis. The stalks were thoroughly drenched with the spray.

The results from the first experiment, in which the strength was only 1 to 700, indicated clearly that the spray had absolutely no effect on the larvæ. No larvæ were killed in the mines. The results of the second experiment were more encouraging. Young larvæ just beginning their mines were found killed by the strength of 1 to 500. Full-grown or nearly full-grown larvæ either went into pupation soon after the spraying, or emerged from the mines to the surface of the stalks; later, the larvæ that emerged were found either dead or transformed into the pupa stage. This experiment was repeated several times with the same results.

Experiments for control of the flies

In the experiments for killing the flies the spraying was done both out of doors and on plants in the insectary. For the first experiment potassium arsenate was used at the rate of 1 part to 45 parts of water, twelve pounds of sirup being added in order to attract the flies. For the second experiment arsenate of lead, 2 pounds to 50 gallons of water, was used, with twelve pounds of sirup added in order to attract the flies. In these experiments the plants were thoroughly drenched with the spray. Within the insectary a plant in a cage was sprayed and flies were afterwards placed in the cage.

In the first experiment the flies in the cages were found dead twelve to twenty-four hours after spraying. In one cage the flies were found dead within six hours after the spraying was finished. Some injury to the plants was noticed, however, the next day. This was due undoubtedly to the potassium that went into solution. In the second experiment

the flies in the cages were found dead within thirty-six to forty-eight hours. The action of the poison on the flies was slow, but they eventually succumbed. Out of doors it was impossible to determine definitely the effect of the spray on the flies, for dead flies were found both under the plants that were sprayed and under those that were not sprayed.

Conclusions

From the few experiments made and the small number of plants used, it was impossible to draw very safe conclusions. The writer believes that more experiments are necessary in order to determine the kind and strength of insecticide that would be effective in killing the larvæ. "Black-leaf 40" tobacco extract, in the proportion of 1 gallon to 500 gallons of water, appears to be adequate.

In the case of adults, although the results within the cages were encouraging, field experiments on a large scale should be conducted in order to demonstrate whether the spray used will rid asparagus of the miner. The writer believes that when both the miner and the beetles are present the use of arsenate of lead in the proportions mentioned, with sirup added, will control both pests. It would seem, therefore, that by pulling the infested stalks in late fall or early spring and by the use of the spray for the flies and beetles, the miner can easily be exterminated.

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THE TWELVE-SPOTTED ASPARAGUS BEETLE

(*Crioceris duodecimpunctata* L.)

Order, *Coleoptera* Family, *Chrysomelidae*

D. E. FINK

To the general reader, as well as to the entomologist, the history, distribution, and habits of the twelve-spotted asparagus beetle afford one of the most interesting accounts that could be written about any insect pest. The mysterious introduction of this species into the United States, the discovery of its presence near Baltimore, Maryland, the rapid spread from that center, the keen race northward with the common species, *Crioceris asparagi*, the simultaneous arrival in Canada of the two species, and their progressive advance westward, are only a few of the many interesting phases of the history of the twelve-spotted beetle.

Like its rival the " blue species " (*Crioceris asparagi*), this insect feeds entirely on asparagus. In general habits, however, the twelve-spotted beetle, or " red species," differs in many respects from the common asparagus beetle. Appearing early in spring at almost the same time as does the common asparagus beetle, egg-laying by the twelve-spotted beetle does not begin until the middle of June or later — in fact, not until the flowers of the asparagus stalks have been fertilized, and in many cases not until the berries have begun to form. In contrast to the common species, whose eggs are very conspicuous, the eggs of the twelve-spotted beetle are hard to find. The female hides her eggs among the narrow, thin branches, and the color of the eggs resembles so closely the color of the branches that the eggs not only are rendered very inconspicuous but also require close inspection before they can be found. Also, the larvæ have the interesting habit of boring into a berry as soon as they are hatched. With the exception of the adult stage, when their bright orange color and black spots render the insects very conspicuous, the phases of their life cycle are more or less unnoticeable, yet at the same time they are extremely interesting.

HISTORY AND DISTRIBUTION

Just how or when the twelve-spotted asparagus beetles were introduced into this country from Europe will probably never be known. So far as can be gleaned from the literature of the subject, the insects were first observed in 1881 near Baltimore, Maryland, by Otto Lugger. The assumption at that time was that the species had existed in this country for several years prior to its discovery by Lugger. Lugger mentions that when discovered the insects were feeding on volunteer asparagus plants.

For about ten years after its discovery no mention of the species appeared in any of our literature. In 1892 A. P. Gorden reported finding the beetle in Cummings, Carroll county, Maryland. In the same year it was reported from Gloucester county, New Jersey. J. B. Smith says, in his Nineteenth Report (1898): "First example of the beetles was found on volunteer plants near railroad not far from Swedesboro, Gloucester county, in 1892. The numbers present made it certain that it had been with us for two years at least. Insects did not like dense growth but were found on isolated plants in cultivated beds or on volunteer shoots." By 1897 the beetles had reached Monmouth county in the east central part of New Jersey. When spreading from Maryland to New Jersey they established themselves in northern Delaware.

During the ten years subsequent to its discovery, the twelve-spotted beetles evidently multiplied to such an extent that their ravages began to attract the attention of growers wherever they made their appearance. Throughout their progress northward their invasion was always accompanied by serious damage and loss to asparagus-growers. In 1893 the pest appeared in Monroe county, New York. Lintner says, in the Twelfth Report of Insects of New York (1897): "Found the beetles infesting an asparagus bed in Brighton, Monroe county, New York, in comparatively small numbers in 1893 on the farm of S. J. Robbins." From that date the beetles continued their advance from one county to another in New York State. By 1899 they were distributed in the following twelve counties: Nassau, Schuyler, Niagara, Wyoming, Chautauqua, Allegany, Monroe, Albany, Suffolk, Wayne, Yates, and Erie.

In 1894 the beetles were found at Frankford Junction, Philadelphia. By 1898 they had spread over New York, New Jersey, Delaware, Maryland, and Pennsylvania, and were still continuing their progress northward. In that year they made their first appearance in Canada. Fletcher states that "both species were found in Canada during the summer of 1898 and were equally abundant." In 1901 the beetles began their spread westward. Up to the present time they occur as far west as Ohio and as far north as to include the Niagara peninsula. Since the first observance of the twelve-spotted asparagus beetles near Baltimore in 1881, the insects have been reported from Canada and from the following States: Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Ohio, Massachusetts, and Maine.

NATURE AND EXTENT OF INJURY

In early spring after the asparagus shoots have begun to appear above the ground, the hibernating beetles emerge and begin to attack growing shoots in the same manner as do the beetles of the common species. Obser-

vations in the vicinity of Ithaca, New York, failed to show any attack on cutting beds, but the beetles were found in large numbers on volunteer plants growing near a cutting bed. Later, when the cutting season is over and the shoots have begun to branch out, the attack on asparagus plants is begun in earnest. The beetles at this time feed mainly on the stalks and branches, gnawing the epidermis and biting out large pieces. Even the larger branches are entirely destroyed by the incessant and voracious appetites of the beetles. They feed also to some extent on the very small branches. Later, the beetles feeding on the branches and stalks feed to a large extent on the blossoms and berries. The berries are attacked and eaten with relish by the beetles, and the larvæ, almost immediately after they are hatched, seek out and enter the berries, leaving one berry for another until they have become matured.

To seed-growers the destruction of the berries is unquestionably a severe loss, while to asparagus-growers the stalks are essential for the full development and growth of the asparagus roots for the following year; hence, the damage done by the beetles and larvæ is considerable, especially when they occur in great numbers. V. H. Lowe, in his Fifteenth Report (1896), stated that there were more of the twelve-spotted beetles than of the common species, and that several growers had given up the fight and plowed under their asparagus beds. Lintner, in his Twelfth Report (1897), mentions that this species eats into growing shoots more than does the common form, and makes them unfit for market. J. B. Smith, in his Nineteenth Report (1898), mentions having found the larvæ feeding on foliage. Professor Lochhead, in his Thirty-second Report (1902), states that "the beetles about St. Catherines did much damage" and "seemed to gnaw the epidermis as shoots were peeping above ground before ready to cut for market."

DESCRIPTION OF STAGES

The adult

The adult beetles are about seven millimeters, or a quarter of an inch, in length. They are wider than the common species and have a cylindrical thorax and a roundish head. The eyes are prominent. In color the entire body is a uniform orange-red except the following parts, which are black: eyes, antennæ, coxæ, tarsus, tip of femur and of tibia, twelve spots on elytra, scutellum, and ventral parts of thorax. The elytra cover the entire abdomen and extend somewhat beyond the apex of the abdomen.

The egg

The egg is of the same general shape and size as that of the common species, slightly over a millimeter in length. When first deposited the

egg is light yellow or orange in color and remains so for several days, turning later to a light green. Several days before hatching one end of the egg becomes extremely dark, and just before hatching this dark part can be distinguished as the black head of the larva inside the eggshell.

The larva

In form and general appearance, but not in color, the larva resembles closely that of the common asparagus beetle.

First stage.— When first hatched the larva is slightly over a millimeter in length, with black head and legs and a black spot on either side of the third segment. The color of the body is pale yellow to pale orange. The first thoracic segment has two long, dark brown plates. The body tapers gradually toward the anal segment.

Second stage.— With the first molt the head assumes a pale yellow color and the body a deeper orange. The larva measures about four millimeters in length in this stage.

Third stage.— After the second molt the larva has nearly the same general appearance as after the first molt, except that it is much larger. The color of the body is not so strikingly orange, but varies much with different larvæ. Some are brownish yellow, others are light orange, and still others are grayish yellow or orange. The head is decidedly yellow and the legs are light brown. Each segment except the anal has a pair of spiracles, one on either side.

The cocoon.— The cocoon is merely a cell made in the soil, and consists of tough silk spun by the larva. It is elongate oval in shape, with particles of soil adhering to the outside giving it a somewhat irregular appearance. On the inside the cocoon is perfectly smooth and fits snugly about the larva.

The pupa

Within two to three days after the larva has entered the soil and made its cell, it pupates. At this time the pupa is light yellow. No eyes are visible, but the antennæ, legs, and wing-pads appear very distinct and are white. Within a week the eyes become distinct and are brown in color, and the legs begin to look yellow with the black markings very apparent.

LIFE HISTORY AND HABITS

In spring — about the middle of May or earlier, depending on the season — the adult beetles of this species emerge from their hibernating places and begin to gnaw the tender asparagus shoots. This is about a week later than the beetles of the common species emerge. At this time the insects feed mainly on the stems of the sprouting shoots, and

when the cutting season begins they are found in large numbers on volunteer plants. In June they are found feeding also on the blossoms and fruit. The beetles take flight readily when disturbed, but they also dodge around the stem as do those of the common species. As stated by Chittenden, the beetles when handled often produce a crackling sound, which is effected by rubbing the tip of the abdomen against the elytra.

Copulation begins soon after the appearance of the adults, and lasts throughout the months of May and June and even into the first week of July. Egg-laying, however, does not begin soon after copulation; in fact, egg-laying does not begin until after asparagus plants have either blossomed or begun to form the berries. This occurs usually about three weeks or more after the appearance of the beetles in spring.

Deposition of eggs

The female chooses plants that have many small branches (popularly spoken of as leaves), and probably by preference also those branches that bear blossoms or berries. The eggs are deposited singly on their sides on a single branch or between two branches. In oviposition the female takes up a position on a stem, thrusts her ovipositor beneath a branch, and deposits the egg. The egg, being viscid, adheres firmly to the side of the branch. The female then moves along the stem and repeats the process. Three eggs were observed to be thus deposited within forty-five seconds.

The eggs are elongate oval, slightly broadened at one end, perfectly smooth, and with no sculptural markings. When first deposited they are light orange in color; after a few days they become dark green. Several days before hatching one end of the egg becomes black, thus indicating the black head of the larva within the egg. Incubation lasts for seven to twelve days.

Habits of the larva

The larva does not begin to feed on the small branches as soon as it is hatched, but wanders about the stem. The writer has observed a newly-hatched larva moving about a branch for hours without feeding; as soon as a berry was supplied, however, the larva immediately began to bore into it, and within forty-five minutes the larva had made its way to the inside of the berry. The larva shows a preference as to the point where it enters the berry. In every instance observed, the newly-hatched larva bored and entered beneath one of the sepals or between two sepals covering the berry at the calyx end. The sepal thus conceals the entrance of the larva into the berry. This instinct of concealment

FIG. 136.— *Twelve-spotted asparagus beetle, enlarged and natural size*

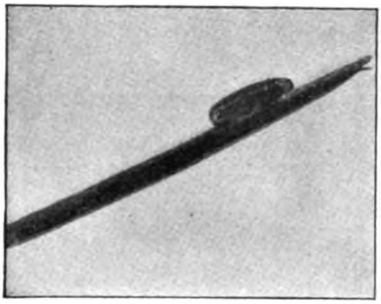

FIG. 137.— *Egg of beetle on branch of asparagus*

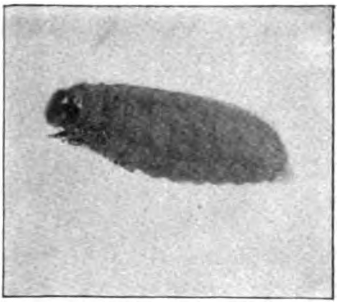

FIG. 138.— *Larva of twelve-spotted asparagus beetle*

FIG. 139.— *Pupal case from soil*

FIG. 140. — *Pupa, dorsal view*

FIG. 141.— *Pupa. ventral view*

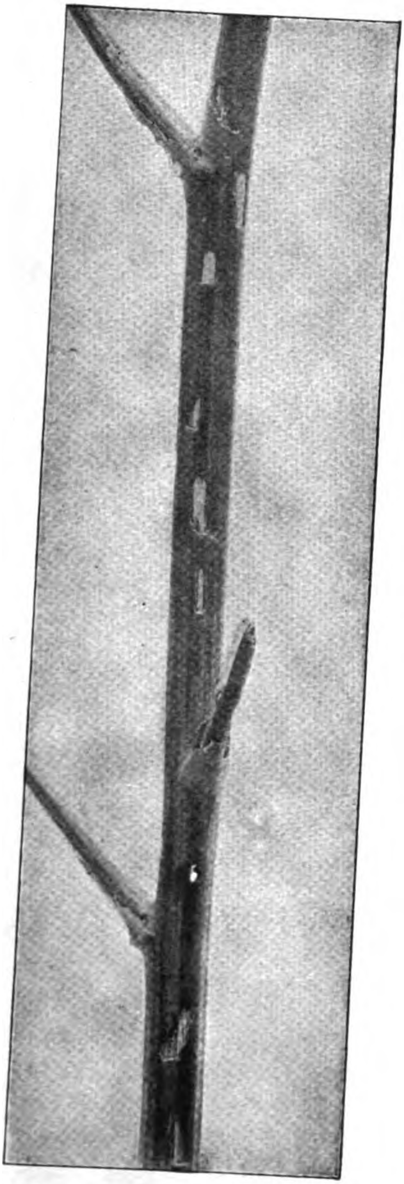

FIG. 142.— *Injury to asparagus caused by the adult beetles*

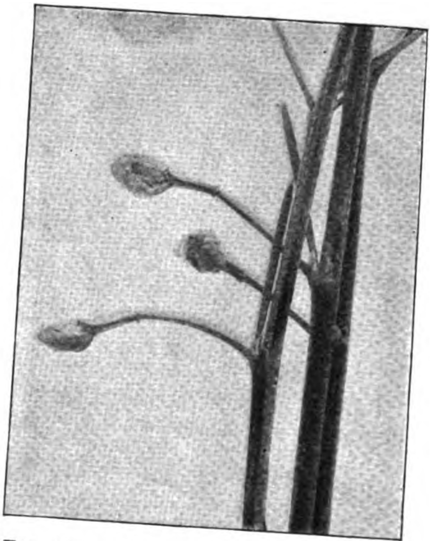

FIG. 143.— *Buds, partly eaten by asparagus beetles*

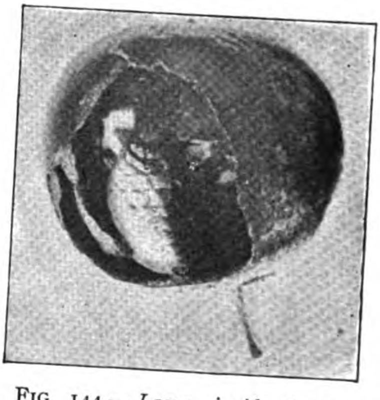

FIG. 144.— *Larva inside berry enlarged*

FIG. 145.— *Larva inside berry, slightly enlarged*

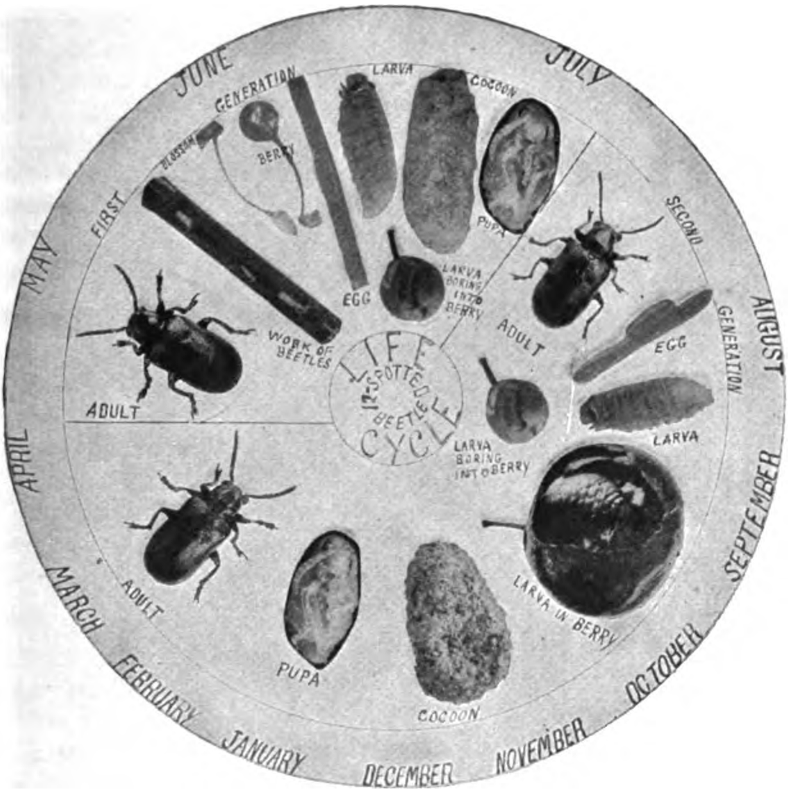

Fig. 146.— *Life cycle of the twelve-spotted asparagus beetle*

undoubtedly serves as a means of protection. The surprising feature of the matter is that the writer has never found more than one larva within a berry.

The number of molts

The larva remains in the first berry for several days, eating out the soft, juicy pulp and the tender seeds. Before leaving for a second berry the larva molts and the cast skin is found inside the discarded berry. The larva may molt again before leaving the second berry, but sometimes the second molt does not occur before the larva leaves the third berry. After the second molt a larva can eat the entire contents of a berry within twenty-four hours or less, depending on the size of the berry. By the time the larva has become full-grown it has cast its skin twice. It may feed on as many as four berries before finally entering the soil. A millimeter long when first hatched, the larva is eight millimeters long when full-grown.

The pupa

Within a day after a pupa has entered the soil it makes a tough cell, or cocoon, of silk. In shape this cocoon is oblong oval. Particles of soil adhere to the outside. Within two days after making the cell the larva pupates. In the cocoon the third cast skin is found after the larva has changed to a pupa.

The pupa is yellow in color. Usually twelve to sixteen days are required for its transformation to the adult stage.

Seasonal summary of life history

The beetles emerge about the middle of May — usually about a week later than the common species. Egg-laying does not begin until three to four weeks after the emergence of the beetles, or about the middle of June in the vicinity of Ithaca. Within seven to twelve days the eggs hatch and the larvæ immediately enter the berries. A week to ten days is spent within the berries before the larvæ become mature, when they enter the soil. Pupation lasts twelve to twenty days before the adults appear. In the vicinity of Ithaca the adults of the first generation begin to emerge about July 20. Egg-laying for the second brood commences about August 1 and the larvæ hatch about August 9.

METHODS OF STUDY

In order to determine the period of egg incubation and to ascertain the exact number of times that the larva casts its skin, it was necessary to adopt some method whereby the larva could be isolated, and branches

DATA OF LARVÆ REARED TO ADULT STAGE IN THE INSECTARY. FIRST GENERATION

Experiment	Larva hatched	Entered first berry	First molt	Entered second berry	Second molt	Entered third berry	Entered fourth berry	Entered soil	Made cell	Pupated	Adult emerged	Total number of days
A.......	June 30	June 30	July 3	July 3	July 5	July 5	.....	Larva	died	.....	.....	.....
B.......	June 30	June 30	July 3	July 3	July 5	.....	.....	July 6	July 7	July 9	Died	.....
C.......	June 30	June 30	July 3	July 3	.....	.....	.....	July 5	July 7	July 8	July 19	20
D.......	June 30	June 30	July 3	July 3	July 5	July 6	.....	July 8	July 9	Died	.....	.....
E.......	June 29	June 29	July 4	July 4	July 6	July 6	.....	July 8	July 8	July 9	Died	.....
F.......	June 30	June 30	June 30	July 3	July 5	July 5	July 6	July 8	July 9	July 11	July 24	25
G.......	June 30	June 30	July 4	July 4	.....	.....	.....	July 6	July 7	July 9	July 20	21
H.......	July 6	July 6	July 9	July 9	July 12	.....	.....	July 14	July 15	July 16	July 29	24
I.......	June 30	June 30	July 3	July 3	July 5	July 7	July 8	July 9	July 10	July 12	July 26	27
J.......	June 30	June 30	July 4	July 4	July 6	July 6	.....	July 8	July 11	Died	.....	.....
K.......	July 3	July 3	July 6	July 6	July 8	.....	.....	July 8	July 10	July 12	July 31	29
L.......	June 30	June 30	July 4	July 4	July 6	July 6	.....	July 7	July 9	July 10	July 24	25
M.......	June 30	June 30	July 3	July 4	July 5	July 5	.....	July 8	July 9	July 11	July 31	32

Data of Larvæ Reared to Adult Stage. Second Generation

* Experiment	Eggs deposited	Larva hatched	Entered first berry	First molt	Entered second berry	Second molt	Entered third berry	Entered soil	Pupated	Adult emerged	Total number of days	Remarks
A........	Aug. 1	Aug. 9	Aug. 9	....	....	....	....	Aug. 18	Aug. 19	Aug. 31	31	One berry eaten
B........	Aug. 1	Aug. 9	Aug. 9	Aug. 16	Aug. 16	....	....	Aug. 18	Aug. 20	Sept. 4	35	
C........	Aug. 3	Aug. 18	Aug. 10	....	....	....	....	Aug. 20	Aug. 23	Sept. 8	37	Same as A
D........	Aug. 3	Aug. 10	Aug. 10	....	....	....	....	Aug. 20	Aug. 21	Aug. 28	26	Same as A
E........	Aug. 3	Aug. 10	Aug. 10	....	....	....	....	Aug. 21	Aug. 23	Sept. 7	36	Same as A
F........	Aug. 3	Aug. 12	Aug. 12	....	....	....	....	Aug. 16	Aug. 18	Sept. 6	35	Same as A
G........	Aug. 3	Aug. 12	Aug. 12	....	....	....	....	Aug. 20	Aug. 21	Sept. 6	35	Same as A
H........	Aug. 3	Aug. 13	Aug. 13	....	....	....	....	Aug. 23	Aug. 26	Sept. 9	38	Same as A
I........	Aug. 3	Aug. 13	Aug. 13	....	....	....	....	Aug. 23	Aug. 25	Sept. 12	41	Same as A
J........	Aug. 5	Aug. 12	Aug. 12	....	....	....	....	Aug. 25	Aug. 27	Sept. 9	36	Same as A
K........	Aug. 6	Aug. 13	Aug. 13	....	....	....	....	Aug. 23	....	Sept. 11	37	Same as A
L........	Aug. 6	Aug. 12	Aug. 12	Aug. 19	Aug. 20	....	....	Aug. 23	Aug. 25	Sept. 8	34	
M........	Aug. 6	Aug. 12	Aug. 12	....	....	....	....	Aug. 21	....	....	......	Larva did not pupate. Found dead
N........	Aug. 6	Aug. 12	Aug. 12	....	....	....	....	Aug. 20	Aug. 23	Sept. 5	31	Same as A
O........	Aug. 6	Aug. 12	Aug. 12	....	....	....	....	Aug. 23	....	....	......	Larva did not pupate. Found dead
P........	Aug. 9	Aug. 14	Aug. 14	Aug. 22	Aug. 23	....	....	Aug. 26	....	Sept. 8	31	
Q........	Aug. 9	Aug. 14	Aug. 14	....	....	....	....	Aug. 25	Aug. 26	Sept. 12	35	Same as A

containing eggs were placed in vials. These branches were collected on the day when the eggs were deposited on them. Branches containing berries were also placed within the vials, so that the larvæ might find their proper food immediately after hatching. As soon as a larva hatched and began boring in one of the berries it was isolated in one of the vials half filled with soil. In this vial a second berry was added, to serve as food when the first berry should be discarded. The vials were observed daily, and as soon as a berry was eaten out and discarded by a larva it was examined carefully for the cast skin. This method afforded an excellent means of ascertaining the number of molts of the larva and the number of berries eaten by it. When the larva finally became full-grown it entered the soil within the vial, and there made a cell in which to pupate. The cells could be examined easily and the time required for transformation of the larvæ, as well as the time required for pupation, could be readily ascertained. The adults that issued later were afterwards placed in cages.

METHODS OF CONTROL

With the available knowledge of the habits and life history of this insect the methods of control easily suggest themselves. Since the larvæ live and feed entirely within the berries, it would seem as if no insecticide would be of value in their control. Although no experiments were conducted to that effect, the writer believes that if the berries are sprayed with some poison, such as arsenate of lead, as soon as they are formed, the larvae when hatched will get some of this poison in their first meal. There seems to be no necessity for this extra spraying, however, unless the spraying for the beetles has been delayed or neglected until the adults have begun ovipositing. As the beetles do not begin to deposit their eggs until three to four weeks after their emergence in spring, spraying with arsenate of lead — 2 pounds to 50 gallons of water, with two to four pounds of soap added as a sticker or twelve pounds of sirup added when the asparagus miner is present — will effectively destroy the beetles before they have had a chance to deposit their eggs. The arsenate of lead with the addition of sirup has the advantage of destroying both species of asparagus beetles, as well as the asparagus miner.

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Full discussion and bibliography.

1897. Laurent, Phillip.— Doings of societies. Entomological News, vol. 8, p. 230.
The insects found in large numbers at Holmesburg and Lancaster, Pennsylvania, and also at Mt. Airy.

1898. Chittenden, F. H.— Insects that affect asparagus. Bul. 10, n. s., Div. Ent., U. S. Dept. Agr., pp. 57–59.
Full account of the pest.

1898. Felt, E. P.— The asparagus beetles. The Country Gentleman, vol. 63, no. 2379, p. 693.
The twelve-spotted species well distributed along Hudson River valley.

1898. Smith, J. B.— The 12-spotted asparagus beetle. Rept. New Jersey Agr. Exp. Sta. 1898, pp. 463–466.
Life history and remedies.

1899. Sanderson, E. D.— A destroyer of asparagus beetles. American Gardening, May, 1899.
Treats of *Prionidus cristatus.*

1899. Sanderson, E. D.— Farm News, May, 1899.

1899. Felt, E. P.— Asparagus beetles. The Country Gentleman, vol. 64, no. 2433, p. 733.
Traces recent distribution of the species in New York State.

1899. Felt, E. P.— Asparagus beetles. Bul. 20, n. s., Div. Ent., U. S. Dept. Agr., p. 61.
Present in numbers in East Amherst, New York, and found also in vicinity of Albany, New York.

1900. Webster, R. L.— Some insect notes. Entomological News, vol. 11, p. 436.
Found the twelve-spotted species at Buffalo, New York, and at Ontario, Canada.

1900. Smith, J. B.— Ent. Cir. 18, New Jersey State Bd. Agr., p. 2.

1900. Lochhead, W.— Injurious insects of the orchard, garden, and farm for the season of 1899. 30th Ann. Rept. Ontario Ent. Soc., pp. 66–71.
The twelve-spotted species the more common form in Niagara district. Rather destructive in Lincoln and Welland counties.

1900. Lochhead, W.— Canadian Horticulturist, May, 1900, pp. 192–193.
Mention of the insect.

1900. Johnson, W. G.— Notes on insects of economic importance for 1900. Bul. 26, n. s., Div. Ent., U. S. Dept. Agr., pp. 80–84.
Mention of the occurrence of the twelve-spotted asparagus beetle.

1900. Howard, L. O.— Appearance of the twelve-spotted asparagus beetle near New York City. Bul. 22, n. s., Div. Ent., U. S. Dept. Agr., pp. 107–109.
A colony of *C. 12-punctata* was found in the outskirts of Brooklyn, New York; the insects were apparently abundant.

1900. Hutt, W. N.— Asparagus beetles. 30th Ann. Rept. Ontario Ent. Soc., p. 71.
Discussion of both species of asparagus beetles; remedies suggested.

1900. Fletcher, J.— Injurious insects in Ontario during 1899. 30th Ann. Rept. Ontario Ent. Soc., p. 106.
The two species of asparagus beetles were equally abundant and were the cause of loss to asparagus-growers at Queenstown.

1900. Felt, E. P.— 12-spotted asparagus beetle. 15th Rept. New York State Ent., p. 583.
Known to occur in the State at Albany, Newark, Brighton, East Amherst, Buffalo, and Crosby.

1900. Felt, E. P.— The 12-spotted asparagus beetles. Bul. 37, New York State Mus., vol. 8, p. 27.
Known to occur in several places along Hudson River valley. Description.

1901. Lochhead, W.— Insects of the season of 1900. 31st Ann. Rept. Ontario Ent. Soc., pp. 72–75.
The twelve-spotted species appears several weeks later in the spring than does the common species.

1901. Felt, E. P.— 12-spotted asparagus beetle. 16th Rept. New York State Ent., p. 991.
This species has already attained a wide distribution in this State.

1901. Sajo, K.— Die Spargelkäfer. Prometheus, vol. 13, no. 635, pp. 166–171.
Description of species.

1902. Sajo, K.— Die Bekämfung der Spargelfeinde und einige Schlussbetrachtungen. Prometheus, vol. 13, no. 656, pp. 497–499.
The twelve-spotted species is the last to deposit its eggs and the larvæ develop within the berries.

1902. Britton, W. E.— The twelve-spotted asparagus beetle in Connecticut. 26th Ann. Rept. Connecticut Agr. Exp. Sta., p. 174.
It is expected that the species will become established as a pest on asparagus in this State.

1902. Lochhead, W.— Asparagus beetles. 32d Ann. Rept. Ontario Ent. Soc., pp. 43–50.
The twelve-spotted species is found more abundant and leading the common species in its spread westward. Much damage reported about St. Catherines.

1903. Chittenden, F. H.— Principal injurious insects of 1903. Ybk. U. S. Dept. Agr., 1903, p. 566.
Mention of the species.

1903. Britton, W. E.— The twelve-spotted asparagus beetle in Connecticut. Canadian Entomologist, vol. 35, p. 188.
Mention of the species.

1903. Britton, W. E.— *Crioceris 12-punctata*. Ann. Rept. Connecticut Agr. Exp. Sta., 1903, p. 213.
Now regarded as one of the injurious species of the State.

1903. Balkwill, J. A.— Report on insects of the year. 33d Ann. Rept. Ontario Ent. Soc., p. 41.
First record of the twelve-spotted asparagus beetle in London district.

1904. Lochhead, W.— Asparagus beetles. 34th Ann. Rept. Ontario Ent. Soc., p. 36.
Mention of the species.

1904. Lochhead, W.— Some injurious insects of 1903 in Ontario. Bul. 46, Div. Ent., U. S. Dept. Agr., pp. 79–81.
Mention of the species.

1904. Fletcher, J.— Insects injurious to Ontario crops in 1903. 34th Ann. Rept. Ontario Ent. Soc., pp. 62–71.

Remedies discussed: dusting, poisons, and beating the insects.

1904. Britton, W. E.— Insect notes from Connecticut. Bul. 46, Div. Ent., U. S. Dept. Agr., pp. 105–107.

Considered as having become established in the State of Connecticut.

1904. Balkwill, J. A.— Asparagus beetles. 34th Ann. Rept. Ontario Ent. Soc., pp. 20–21.

Mention of the species as traveling gradually westward.

1907. Chittenden, F. H.— Notes on the asparagus beetles. Bul. 66, part 1, Bur. Ent., U. S. Dept. Agr., pp. 9–10.

Distribution of the species.

1907. Lesne, P.— Les insectes de l'asperge. Journal d'Agriculture Pratique, tom 14, pp. 308–311.

The twelve-spotted species comes out in April and begins to feed on the foliage of the asparagus. The larvæ are orange-colored, and transformations take place in the soil. There are two generations.

1910. Fernald, H. T.— Insects of the year. 22d Rept. Massachusetts Agr. Exp. Sta., part II, pp. 70–73.

The twelve-spotted species has now been taken in Massachusetts. It was found fairly abundant at Concord and at Roslindale. This pest passes its early stages in asparagus berries.

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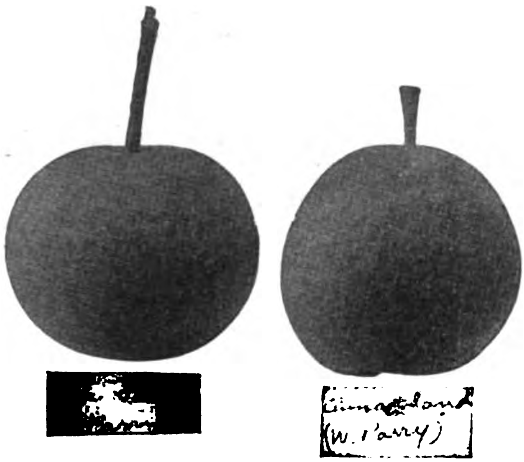
Department of Horticulture

ORIENTAL PEARS AND THEIR HYBRIDS

Under the direction of the late
JOHN CRAIG



By H. R. COX

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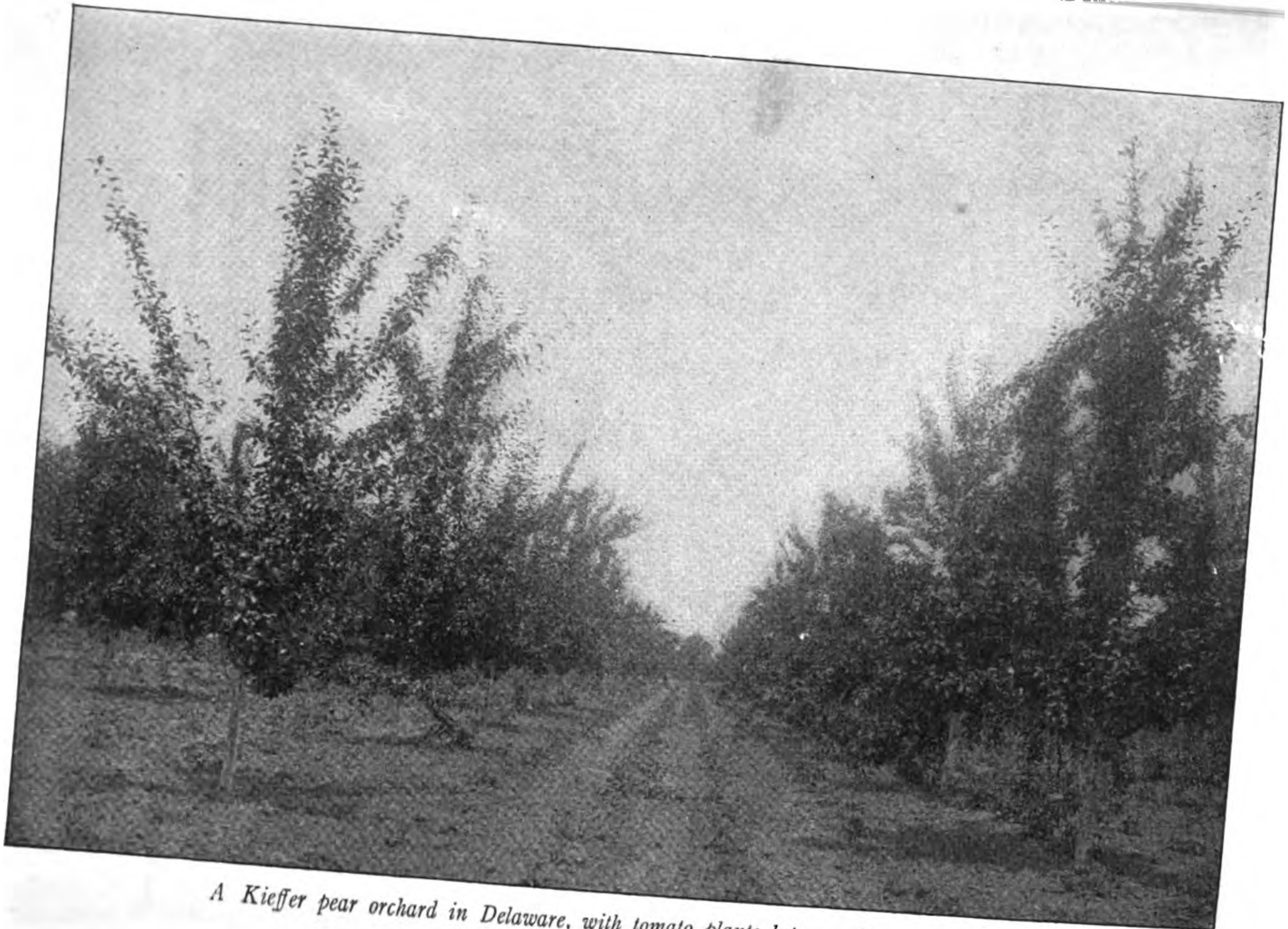

A Kieffer pear orchard in Delaware, with tomato plants between the rows of trees

PREFACE

The data comprised in the following bulletin are the outcome of observations covering almost twenty-five years, made by several persons connected with the Department of Horticulture at Cornell University and later at the New York State College of Agriculture at Cornell University. The study of pears was taken up by L. H. Bailey at Ithaca as early as 1888, and to this work was assigned a part of the horticultural grounds. The studies in pear culture included the Orientals as well as the European varieties, and the Oriental types early found a place in the collection. Most of them proved to be free, vigorous growers with handsome, glossy foliage, bearing freely a fruit of inferior quality as compared with such standards as Bartlett and Anjou. Professor Bailey, then in charge of the Department of Horticulture, conducted a long correspondence for the purpose of determining the history of Oriental pears in North America, and this correspondence, together with pictures and notes, has been available in the preparation of the present bulletin.

The variety descriptions found at the close of this bulletin are based largely on notes made on specimens grown at Ithaca, but somewhat on correspondence by Professor Bailey, H. R. Cox, and the writer of this preface.

All matter pertaining to Oriental pears which had been collected by the Department of Horticulture was placed in the hands of Mr. Cox, a graduate student at Cornell University, who in 1907 undertook the study as a topic of investigation for a master's thesis. The main part of the following pages represents the results of the study by Mr. Cox. In order to bring the matter down to the present time, the writer, assisted by T. Sprague, Jr., corresponded with prominent pear-growers in the leading pear-producing States of the Union.

The chief objects of the study have been, first, to determine the present status of leading members of this interesting group of pears and their commercial importance to the orchard interests of New York; and second, to ascertain whether any well-established body of experience has been collected on the moot question as to whether Kieffer and its allies can be satisfactorily utilized as stocks for the top-grafting of the European varieties and their descendants.

The investigation shows fairly conclusively that the natural range of the members of this Oriental group lies south of New York. In central New York, fruit of Kieffer does not compare favorably with the product of Delaware, Maryland, and States farther south. This is true also of

the product of this variety as grown in western New York; and only on warm soils and in favorable situations, coupled with extra care and careful thinning, does the fruit attain the size, handsome appearance, and quality that characterize the Kieffer of the Delaware peninsula. This does not mean, however, that Kieffer has not been a profitable variety in pear sections of New York. Many orchards have been eminently successful and profitable to their owners, notwithstanding the relatively smaller and less attractive fruit produced as compared with the fruit of regions adapted to its culture.

Our contention is that fruit-growers in this State should leave Kieffer and the like for those sections in which this group attains its highest excellence, for the sufficient reason that, as a rule, they can grow varieties of better quality than the Kieffer in these regions, whereas the more southerly sections are generally restricted to the production of the Orientals. It is a question of adaptation on both sides. In the growing of pears, as well as of apples, the New York orchardist should aim at the production of fruit of first quality; and he has a splendid field in the growing of high-grade pears.

This investigation appears to throw serious doubt on the possibility of making a satisfactory use of Kieffer, Garber, and other Oriental hybrids now planted in orchards, as stocks for top-working varieties of the European strain. It is true that a few successes have been reported; but, in the main, partial or complete failure is the usual result, due apparently to uncongeniality of stock and scion. It is a well-recognized truth that the Orientals are exceedingly vigorous growers, particularly in their younger stages; and there is marked difference in texture of wood, which in itself is frequently a determining factor in the intergrafting of fruit trees. It is not probable that any of the slow-growing varieties of the European type, as Seckel for example, will succeed on Kieffer or Le Conte. On the other hand, a limited amount of evidence is found in favor of Kieffer as a stock for Bartlett, which itself is ranked as a vigorous grower. The presumption is also strong that the grafting must be done with considerable care and at a comparatively early period in the life of the stock.

In the meantime, the Orientals are filling an excellent mission, and are occupying an important place in the pomology of the South in meeting the demands for pears adapted to South Atlantic and Gulf conditions. Although by no means exempt from blight, as some would have us believe, or immune to San José scale, these enemies are seldom fatal to the standard varieties of this strain in the Carolinas, Georgia, Florida, and the lower Mississippi Valley States.

In New York the era of the Kieffer has passed. Orchards of this variety will be planted in the future, but not by the discriminating orchardist.

The furor is over, and growers are wisely setting varieties better adapted to the soil and climate of the Empire State and of much higher intrinsic quality. This is as it should be.

The writer acknowledges with thanks the use of five photographs kindly loaned by the Office of Field Investigations in Pomology of the United States Department of Agriculture. The other illustrations appearing in the bulletin are from the photographic files of the Department of Horticulture.

John Craig

CONTENTS

ORIENTAL PEARS AND THEIR HYBRIDS[*]

H. R. Cox

The Oriental pear, *Pyrus sinensis*, is variously called the sand, Chinese, and Japanese pear. The cultivated varieties of this species, and more especially the hybrids between the Oriental and the common, or European, pear, *Pyrus communis*, constitute the subject of this bulletin.

The species grows wild in Mongolia and Manchuria and is cultivated in China and Japan. In the latter country it is the only cultivated species and was introduced there from China in remote times. The Oriental pear was perhaps the first fruit introduced into the United States from China or Japan, and it has been said that no single element has exerted more influence on pear culture in this country, especially in the Eastern States, than the introduction of this species. Although held in small esteem in Europe except for ornamental purposes, this type of pear has become of considerable importance within the past forty years in this country because of the many desirable and remarkable characters of its hybrids. These hybrids produce fruit of only fair quality at best, but their vigor of growth, their resistance to disease and to insect pests, their early and regular habit of bearing, the beauty of their fruit, and their wide range of adaptability have not only given them first place in regions little adapted to the common pears, but have also made them strong competitors of the latter in localities suited to both. Although in recent years much has been written in reports and periodicals about this type of pear, the facts regarding it are somewhat scattered and unsystematized. An effort is here made to collect all this information, and to prosecute an inquiry among fruit-growers of this and other States regarding several much mooted questions concerning these pears.

POSITION OF ORIENTALS AMONG CULTIVATED PEARS IN THIS COUNTRY

There are many species of pears, but practically all cultivated pears are included in three species:

A large proportion of the varieties grown in the United States and nearly all varieties grown in Europe are of *Pyrus communis*, which grows wild over the larger part of temperate Europe and western Asia. This is the pear of history, many references to it occurring in the records of Syria, Egypt, Greece, and Rome. In ancient times the fruit seems to have been of very poor flavor, and high-quality pears may be said to be a modern development in western Europe. Belgium has the credit for the first

great improvements, of which Van Mons was the leader in the early part of the nineteenth century. Many of the best pears grown in this country have been developed from seed of the best European varieties.

Pyrus nivalis, or the snow pear, is cultivated to a limited extent in Europe but not at all in this country. Its different varieties are grown in Austria, northern Italy, and several of the departments of eastern and central France. They constitute the greater number of the cider pears, used for the manufacture of perry, or pear cider.

The Oriental is the third species of pears that have been subjected to cultivation. The commercial aspects of the varieties of this species, many of which are cultivated in Asia, will not be considered here since the varieties have been planted to only a limited extent in this country. A number of the hybrids, however, have attained great prominence in the United States, among which are Kieffer, Le Conte, and Garber, and it is with these varieties that this bulletin is chiefly concerned.

BOTANY AND EARLY HISTORY

The tree of *Pyrus sinensis* attains a height of twenty or more feet and is remarkable for its vigorous and rapid growth of strong, thick, greenish shoots, its freedom from disease, and its hardiness. The leaves are long pointed and broadly ovate, dark green, shining, and larger than those of *Pyrus communis*, with margins that have sharp, almost bristle-like teeth. The flowers are large, white tinted with pink, and appear shortly before the foliage. The fruit is hard and generally rough, usually with a cavity about the stem; the flesh is warted, gritty, tough, and in flavor poor and insipid; and the calyx nearly always falls before maturity. The species is known in this country in a number of varieties, among which are Daimyo, Gold Dust, Mikado, Hawaii, Siebold, Japanese Sand, Sha Lea (Chinese Sand), and others. The fruits are often nearly apple-like in shape, especially in the russet varieties, but are distinguished by the long stem and the gritty, pear-like flesh. Numerous writers have recognized a number of different types of variations of the species. One of them is probably the *pai li*, white pear, or snow pear (not *Pyrus nivalis*), to which reference has been made by various travelers and horticulturists. This is said to be of large size and of finer flavor than the sand pear type.

Introduction into the United States

The introduction of the sand pear into this country was probably by way of Europe. The first importation into Europe of which there is record was made in 1820 for the Royal Horticultural Society of London by John Peter Wilson, Captain of the ship "Cornwall." The president

of the society, Mr. Knight, grafted the species on an old pear tree in his garden at Downton, where it fruited in 1823. "On the 17th of November

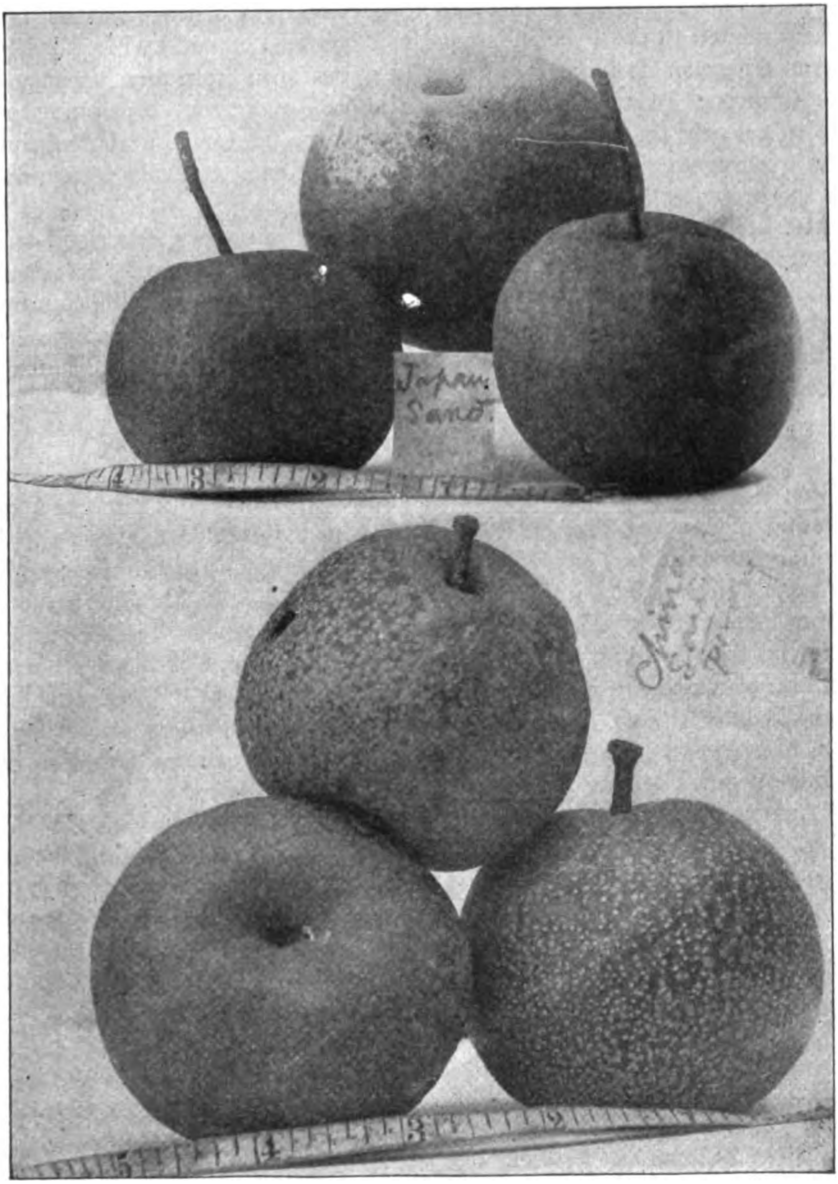

FIG. 147.— *Japanese Sand and Sha Lea (Chinese Sand) varieties*

in that year, a specimen was sent by Mr. Knight to the Society; it was nearly three inches long, and two inches and a half in diameter in the

middle, and nearly equal at both ends, forming almost a perfect oval. The stalk was unusually long, the eye small, close, deeply sunk; the skin pale dull yellow, covered with numerous rough brown spots; the flesh white and crisp, with the flavor of an apple rather than of a pear, and of no particular excellence. The tree appears to be a distinct species, but nearly related to the Pyrus Communis; it has been named by Mr. Lindley Pyrus Sinensis. It is very different in appearance from any variety of the Common Pear. The leaves are almost evergreen, continuing on the tree nearly the whole winter; they are large, and shining dark green. The tree vegetates very early in the spring, when it is easily recognized by the brown color of its young leaves and shoots."*

Mr. Lindley, a botanist, also a member of the society, described and pictured the sand pear several years later and gave the species its scientific name. The earliest known date of its being brought to this country is about 1840 or a few years earlier. It is listed in the catalogue for 1841 of the Prince Nursery of Flushing, Long Island, where it had been introduced from France.

European importers of Oriental fruits

Von Siebold.—"One of the most active and successful importers of Oriental plants was Freiherr v. Siebold, who maintained a nursery and botanic garden in Leiden, Holland, during the first half of the nineteenth century. He was born in Würzburg in 1796 and died in Munich in 1866. Notar Seuffert, President of the Frankischer Gartenbau-Verein, stated that von Siebold imported eighteen new species (many of them *Pyrus*), thirteen of which are in the Royal Gardens at Stuttgart. Among these were *Prunus virgata flore roseo* and *Hydrangea paniculata grandiflora.* Von Siebold was also instrumental in introducing many varieties of Chinese peonies, among which was *Paeonia alba gigantea.*

"Among the publications of von Siebold are the following:

"1. Tabulae synopticae usus plantarum. In insula Dezima 1827. folio. 4 foll.

"2. Synopsis plantarum occonomicarum universi regni japonici. 8. IV. 74 pp.

"3. Einige Worte über den Zustand der Botanik auf Japan, etc. Bonn 1829. 26 pp. 2 tal.

"4. Erwiederung auf W. H. de Vrieses Abhandlung: Het Gezag van Kaempfer, Thunberg, Linnaeus en anderen etc. Leipzig, Voss und Fr. Fleischer 1837. 8. 19 pp. app.

"5. Siebold: Flora Japonica, sive Plantae, quas in imperio japonico collegit, descripsit, ex parte in ipsis locis pingendas curavit. Centuria

*Transactions of the Royal Horticultural Society of London, vol. VI, p. 396. London, 1826.

prima 1835 (Fasc. I-XX); Centuria altera 1842–1844 (Fasc. I-X); Lipsiae, Leopold Voss.

"The following introductions by von Siebold, as listed in his catalogues, are furnished the writer by E. Th. Witte, Hortulanus of the Botanic Garden at Leiden:

1863

Malus spectabilis Desf. var. chin.
Malus spectabilis var. jap.
Malus spectabilis var. jap. semipl.
Malus Ringo Sieb.
Malus (Sorbus) Toringo Sieb.
Malus Toringo var. major
Malus (Sorbus) floribunda Sieb.
Malus (Sorbus) pendula Sieb.
Pyrus communis var. div. japonic.

1866

Malus Toringo Sieb. var. edulis

1867

Malus edulis
Malus (Sorbus) floribunda Sieb. fructubus flavis
Malus spectabilis japonica Kaido
Malus spectabilis japonica semiplena

1869

Malus floribunda pendula Sieb.

1873

Pyrus communis Linn. var. Sieboldii
Pyrus communis Linn. var. Mad. von Siebold

Simon Louis Frères.—"Among other important importers of Oriental fruits the firm of Simon Louis Frères, of Metz, Alsace-Lorraine, should be noted. The writer, while in Europe some four years ago, took occasion to visit this nursery and was given access to its records. It was found that Simon Louis Frères procured the Mikado variety from von Siebold in 1873. In the same year the variety Siebold (Madame von Siebold) was obtained from the same source.

"Among the varieties introduced by Simon Louis Frères are Daimyo and Siebold (Sieboldii). Other varieties that this firm obtained directly from the Orient are De la Chine, 1871, and Chinoise de Tigery, 1871. Simon Louis Frères have grown a considerable number of varieties of Japanese pears from seed. These, they find, in a general way resemble the seedling

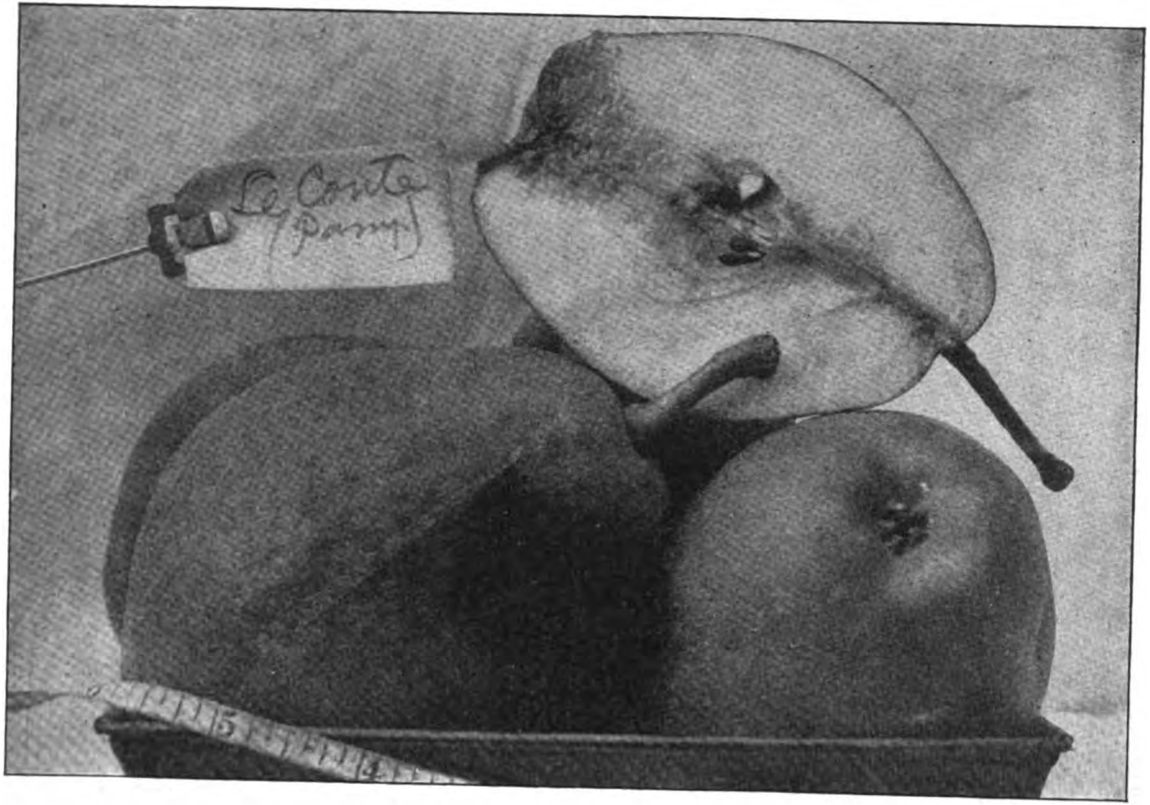

FIG. 148.— *Le Conte pear*

parent in form of fruit. Most of them have long stems, but one or two appeared with short stems and these are good enough for eating.

"The Oriental pear, however, has made little or no headway in France or Germany. Simon Louis Frères have not been successful with Kieffer. The tree lacks much in vigor, which is a surprise, and it is largely superseded by other Japanese sorts. In Metz, and also in France generally, Le Conte is not used as a stock. Possibly this is the cause of the difficulty, and if Le Conte were used as a stock the results might be much better."—J. C.

APPEARANCE OF THE HYBRIDS

The first hybrid to appear in this country was Le Conte. About the year 1846 Major John Le Conte, a resident of New York, had a number of fruit trees and other plants sent to his niece, Mrs. J. L. C. Hardin of Liberty county, Georgia, from the nursery of Thomas Hogg. Among other plants was a tree of the sand pear, which Mr. Hogg had obtained from Ferdinand Potter, a nurseryman of Providence, who in his turn had procured it from the Prince Nursery. Contrary to expectations, the fruit proved to be much better than the Sha Lea (Chinese Sand) pear as known up to that time. The variety was given the name "Le Conte," but its male parentage will never be known. It has been said to have been Bartlett, but this statement lacks good authority. The fact is that this variety, like other so-called hybrids, may not be a hybrid at all but merely a sport or seedling variation. The species has a marked tendency toward variation, and it is not necessary, therefore, to suppose that Le Conte was the result of hybridizing.

For many years Peter Kieffer, of Roxborough (near Philadelphia), grew the Sha Lea pear and sold the seedlings as ornamental trees. It happened that some Bartletts were growing near the sand pear trees, and the branches of the two kinds were allowed to intermingle. He noticed that one of his seedlings possessed different foliage from the remainder, and this he saved. This tree fruited in 1873, producing a considerable crop of large and beautiful pears. These were first exhibited at the Centennial Exposition in 1876 and were given the name "Kieffer."

Garber was produced by Dr. J. B. Garber, of Columbia, Lancaster county, Pennsylvania, who died about 1885. This variety originated from seed of the Sha Lea pear, and was put on the market in 1880 by William Parry.

In 1854 S. F. Smith, of Marietta, Ohio, received from New York a pear tree of the Oriental type called Cincincis. Near the place where he planted it was a small orchard of common pears, among others the Bartlett, Seckel, Flemish, and Angouleme. He planted seed from the Cincincis tree and fruited a large number of seedlings. A few specimens

were sent to D. M. Dewey, of Rochester, with the request that he name them and have plates made of them. He suggested the following names for different seedlings: Smith's Hybrid, Dewey Premium, Commodore Perry, Smith's Marietta, Admiral Farragut, and Cincinnatus. Mr. Smith was one of the first nurserymen to raise and offer for sale the new race of pears.

Although there are other Oriental hybrids, they are not of much importance, nor do the facts concerning their origin possess so much historical interest as do those of the hybrids named above.

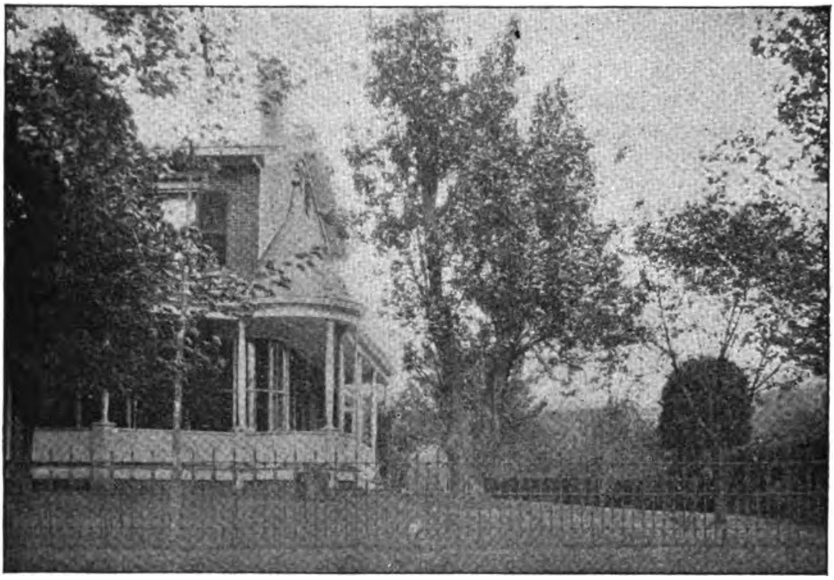

FIG. 149.— *Original tree of Cincincis pear, nearly sixty years old, at the home of S. F. Smith, Marietta, Ohio*

STATUS IN THE POMOLOGY OF THE UNITED STATES

Importance of the hybrids in the pear-growing industry of the country

Soon after the Civil War the planting of Le Conte was begun in the Southern States, especially in Georgia, and the area of its cultivation spread with remarkable rapidity. The inability to grow the common varieties of pears throughout this whole region, together with the unprecedented vigor of growth, productivity, and beauty of fruit of Le Conte, gained for it an instant popularity. Large orchards were set out, and the fruit, which proved to be a good shipper, brought high prices in the northern market. But unfortunately the deadly destroyer, fire blight, penetrated into the trees and in a few years had swept away many orchards.

In the meantime Kieffer had been more slowly gaining recognition in the North. On the failure of Le Conte in the South the planting of Kieffer was begun in that region also, and for a long time it was thought to be less subject to blight than was Le Conte. Later experience, however, seems to indicate that the two varieties are about equally subject to this disease. In the period between 1880 and 1890 plantings of Kieffer were made in great numbers. The nurseries were taxed to their utmost capacity in the propagation of this variety, which often sold considerably above the prices usually obtained for standard varieties. A typical example of its importance was shown by a Missouri nurseryman's offering for sale 50,000 Kieffers and 25,000 Garbers in a total of 100,000 pear trees. Large orchards, many of them of one hundred acres or more, were planted, and, according to the census returns of 1900, to the Kieffer may be attributed perhaps ninety per cent of the increase in pear trees in this country during the preceding decade. There are probably more trees of this variety than of any other in the United States to-day. Although Bartlett is the most extensively grown pear on the Pacific coast, where it represents nearly ninety per cent of the pears grown, Kieffer is by far the most important variety in the entire country east of the Rocky Mountains.

Statistics of pear-growing in 1890 *and* 1900

The number of pear trees of all varieties in 1900 in the ten most important pear-producing States, together with the yield of fruit for the year 1899, is here given. The figures for 1890 also are shown. It is seen that New York, which had by far the largest number of trees in 1890, had dropped to second place in 1900.

States	Number of trees		Number of bushels		Percentage of increase	
	1900	1890	1899	1890	Trees	Bushels
United States....	17,716,184	5,115,055	6,625,417	3,064,375	246.4	116.2
California.......	2,512,890	695,738	1,912,825	577,444	261.2	231.3
New York.......	2,183,909	1,173,206	960,170	588,767	86.1	63.1
Michigan........	1,187,110	270,482	170,702	194,099	338.9	—12.1
Texas...........	1,044,680	37,370	166,418	17,034	2,695.5	877.0
New Jersey......	926,117	274,015	790,818	80,664	238.0	880.4
Ohio............	921,412	353,232	244,565	279,831	160.9	—12.6
Indiana.........	868,184	204,579	231,713	157,707	324.4	46.9
Pennsylvania....	815,349	325,062	434,177	144,534	150.8	200.4
Illinois..........	795,551	84,067	133,745	57,090	846.3	134.3
Maryland.......	690,483	274,543	301,702	60,292	151.5	400.4

The average number of pear trees per farm in 1900 and the average number of bushels of fruit per farm in the nine localities most important in this regard, are as follows:

	Number of trees per farm	Number of bushels of fruit per farm
Delaware	147.7	58.5
California	141.0	105.8
Colorado	139.0	15.8
New Jersey	96.8	82.6
District of Columbia	74.5	31.2
Arizona	55.7	23.0
Maryland	49.3	21.6
Utah	45.8	11.8
Idaho	36.3	7.1

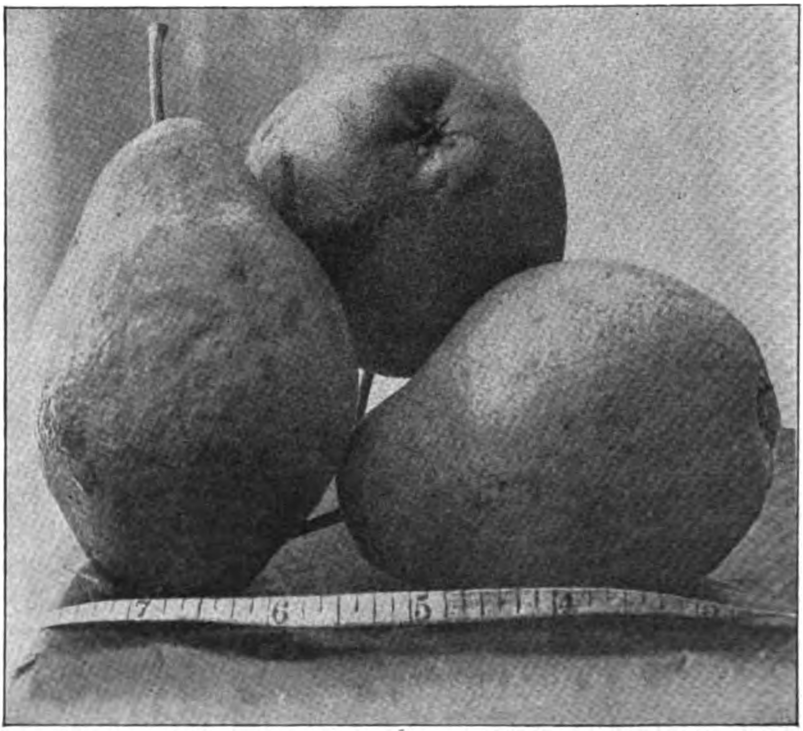

FIG. 150.— *Kieffer pears*

The States of Maryland, Delaware, New Jersey, and Pennsylvania (in its eastern part) constitute the greatest pear-growing region of equal area in the United States, and, of these four States, New Jersey is the largest producer. Statistics of production for this State, therefore, give some idea of the relative importance of the hybrid varieties in this whole region as compared to the common varieties. As the result of an inquiry made in 1899 by the New Jersey Agricultural Experiment Station for the purpose of determining the most profitable and desirable varieties of pears for commercial planting in the State of New Jersey, the order of preference was as follows: Kieffer, Bartlett, Le Conte, Angouleme, Seckel, Lawrence. Of the orchard area represented by this report, which is probably a fair average for the whole State, 68 per cent was set to Kieffer and 24 per cent to Bartlett, leaving 8 per cent for all the other varieties. At the time of this inquiry in 1899 there were approximately 5,650 acres in the State devoted to commercial pear-growing, thus giving to the 819 growers an individual average of 6.9 acres.

Statistics of pear-growing in 1910

The following table shows a marked decrease in the number of trees. New York again takes the lead among pear-growing States, exchanging places with California.

States	Number of trees		Number of bushels		Percentage of decrease	Percentage of increase
	1910	1900	1909	1899	Trees	Bushels
United States	15,172,000	17,716,184	8,841,000	6,625,417	14.4	33.4
California	1,411,000	2,512,890	1,928,000	1,912,825	43.8	0.8
New York	2,142,000	2,183,909	1,343,000	960,170	1.9	39.9
Michigan	1,136,000	1,187,110	666,000	170,702	4.3	290.2
Texas	558,000	1,044,680	111,000	166,418	46.6	—33.3
New Jersey	732,000	926,117	463,000	790,818	21.0	—41.5
Ohio	899,000	921,412	375,000	244,565	2.4	53.3
Indiana	709,000	868,184	320,000	231,713	18.3	38.1
Pennsylvania	797,000	815,349	379,000	434,177	2.2	—12.7
Illinois	786,000	795,551	249,000	133,745	1.2	86.2
Maryland	541,000	690,483	367,000	301,702	21.6	21.6
Delaware	450,000	395,000	105,000	156,000	+13.9	—32.7
North Carolina	243,000	139,000	84,000	26,000	+74.8	223.1
South Carolina	105,000	73,000	66,000	20,000	+43.8	230.0
Georgia	263,000	385,000	150,000	49,000	31.7	206.1

Decrease in number of trees of bearing age

In the census of 1900, taken as of June 1, there were reported 17,716,000 pear trees of bearing age, as against 15,172,000 trees in 1910 (census

taken as of April 15), a decrease of 2,544,000 trees, or 14.4 per cent. In 1910 there were 1,276,366 farms reporting pear trees of bearing age, or 20.1 per cent of the total number of farms in the United States. The average number of bearing pear trees per farm reporting is given as 12. No report was obtained in 1900 showing the number of farms on which were pear trees of bearing age.

Nor did the returns of the census of 1900 give the number of trees under bearing age. In 1910, however, 611,788 farms (or 9.6 per cent of the total number) had 8,804,000 trees not of bearing age, or an average of 14 trees per farm.

Increase in production

The last census shows that in 1909 there were produced in the United States 8,841,000 bushels of pears, having a total value of $7,911,000. The production at that time was somewhat greater than it was ten years previously, when 6,625,000 bushels were gathered. The reports of the census of 1900 give no information as to the value of pears.

Range of adaptability

Kieffer finds a congenial home throughout all the Southern States, where it grows to perfection, although its greatest susceptibility to blight in that region as compared with such susceptibility in the Northern States has restricted its area to some extent. It is grown successfully as far south as the northern line of Florida, and even in the northern part of that State. Its thick, leathery foliage and general resistance to drought and heat enable it to withstand the hot, dry, sunny weather of the South. It is grown in large quantities as far north as the latitude of New Jersey and Missouri. In the latter State it was reported in 1893 to be more common than all other varieties combined. North of this latitude and east of Lake Michigan the variety is profitably grown in certain regions that are well adapted to it in climate and soil, the season being too short in many places for it to develop as fine a flavor, color, and size as in the South.

In parts of western New York, in the Hudson River valley, and on Long Island, Kieffer is profitably grown; but it is probable that in this State there are other localities where it has been planted of late years, which will prove to be ill adapted to the variety. If the common varieties grow better in such places it may be desirable to top-graft the Kieffer to Bartlett or to others of the common sorts. There has been much discussion of late years as to whether the common varieties can be top-worked on the hybrids, and as this is a question of much importance to pear-growers in this State it will be considered later.

West of Lake Michigan, on the great prairies north of the fortieth parallel, pear-growing is not a profitable industry because of the rigorous winters. In Colorado, California, and the Pacific Northwest, the hybrids can be grown with success, but most of the plantings in these States are of the common varieties.

The area of Le Conte is similar to that of Kieffer, except that it does not seem to be suited to regions so far north. Garber is grown more extensively in the Middle Western States than elsewhere, in some places to as great an extent as Kieffer; but there is no evidence that it will not succeed equally well in the East.

FIG. 151.— *Garber pear*

In regard to soil and locality, although the hybrids thrive on almost any soil that is not too wet they reach their greatest perfection in light, well-drained soils and on high or sloping sites where the air drainage is good. As a rule, the hybrid pears do best in those localities where peaches succeed well.

Conditions affecting quality

When the hybrid pears were first being introduced, many diverse reports were current regarding their quality. Some of the best-known fruit-growers in the country reported that they were of fairly good quality — not so good, of course, as Seckel or Bosc, but fairly comparable

with Angouleme and Vicar; while other growers were bitter in their denunciation of these varieties. The president of one of the state horticultural societies even went so far as to declare with much positiveness that he would rather eat a chip from the woodpile than a Kieffer pear! This difference of opinion attests to the great variation in quality of the hybrids as grown under different conditions. When grown under unfavorable conditions the flesh is hard and coarse, with little of the real pear flavor but having a raw, immature, acid-like taste. At their best the pears lose this acidity, which is transformed to a rather agreeable quince-like flavor or spiciness, tasting more like the European varieties; and they are fairly juicy.

Two of the principal factors governing quality are the time of picking and the subsequent ripening process. Furthermore, if the growing season of the locality in which the tree is situated is too short, the fruit will not reach full maturity and will be lacking in quality. Fruit taken from trees grown under neglect is often small and knotty.

The tendency of trees of these varieties to over-bear is also a cause of decrease in quality of fruit. On few kinds of fruit trees does thinning seem to pay so well as it does on hybrid pears. If proper thinning is practiced, the fruit is improved in size, color, and flavor and amply rewards the grower for the extra labor. If the fruits are removed so that those remaining are spaced about eight inches apart over the tree, the results will be satisfactory.

Yields and profits

This is, of course, an exceedingly variable factor. Not only does one year differ from another and one region from another, but also in the same region very different results will be obtained by different growers, depending on the soil, on the location, and especially on the care given in regard to cultivation, pruning, spraying, and methods of marketing. As a result of an inquiry into the pear-growing industry of the State of New Jersey in 1899, made by the New Jersey Agricultural Experiment Station, it developed that sixty per cent of the commercial growers of the State mentioned Kieffer as their most profitable variety and sixteen per cent named Bartlett. The yields of all varieties of pears in that State for the three years previous to 1899 ranged from 1 to 350 barrels per acre, with an average of 83.1 barrels. The season of 1899 gave the highest average yield, 99.4 barrels, and 1898 gave the lowest, 68.2 barrels. Representing, as these averages do, a large number of orchards through three years of varying conditions, they may be taken as indicative of yields likely to result in other years.

The gross returns from the commercial pear orchards of New Jersey varied from $56.50 to $1,220 per acre during the three years, with a

general average of $327.49. The net receipts varied from $25 to $950 per acre, with an average of $265.45. These are indeed very good returns, but it must be remembered that these figures represent the high tide of the hybrid varieties, when they brought better prices than they have in the last few years. Net returns of late years have been somewhat vari-

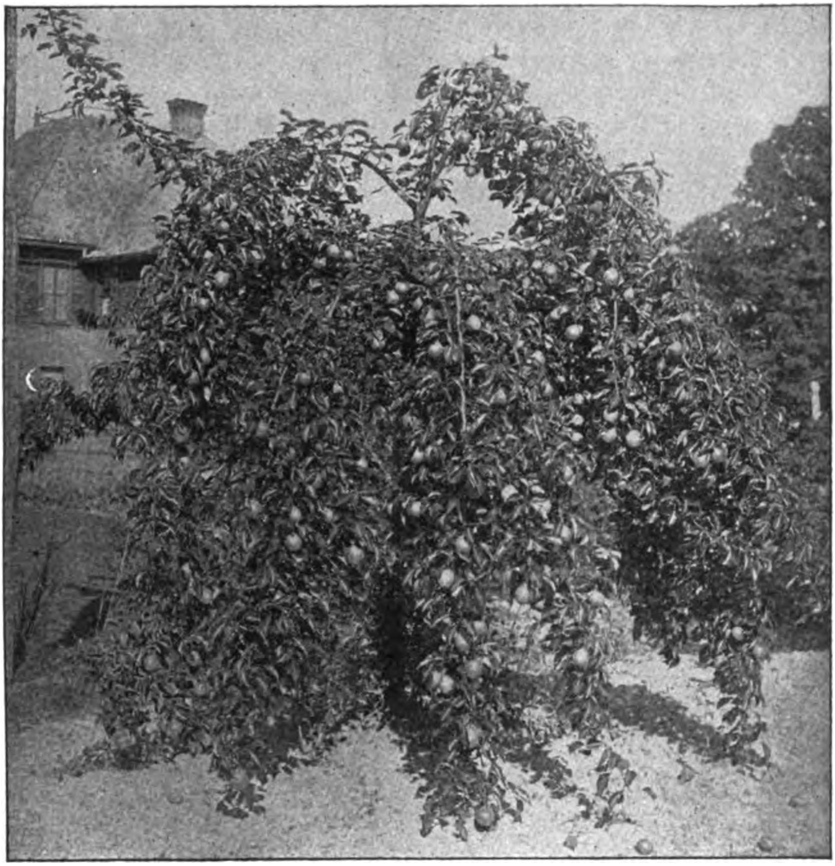

FIG. 152.— *Sikaya pear tree*

able. In some years it hardly pays to pick and market the crop; in other years the crop yields a fairly good profit. The president of the New Jersey State Horticultural Society, in his annual address in January, 1907, said that Kieffer was still the most profitable pear to grow in that State, all things considered. The general pear crop for the preceding year, he stated, was nearly a failure, while the Kieffer crop was heavy.

When sold at canneries the price is often as low as 15 or 20 cents per basket containing five eighths of a bushel, and 25 to 30 cents is considered a good price. As given above, the average yield in New Jersey for three years was 83.1 barrels, or practically 400 baskets. In well-cared-for orchards the yield is sometimes as high as 1,000 baskets per acre. If the pears are of good quality, more money can often be made from them by placing them on the market than by sending them to a cannery, especially if the grower has access to a good local market.

Decreasing demand.—Within the past two or three years the demand for the hybrid varieties has diminished to a marked extent and much less planting has been done. A reliable nurseryman estimates that the plantings of Kieffer on the eastern coast—in Delaware and eastern Maryland—have fallen off fifty or seventy-five per cent in the last three years, which is doubtless fairly representative of the rest of the country; and this has been in the face of a smaller output of pears from California, due to the destruction wrought by blight in that State. The probable status of these varieties in the future is a question with which every grower should concern himself before setting out an orchard. As the prices now obtained for the fruit are very low in some years, there is a possibility that these orchards will become poor property. On the other hand, it is more than possible that the demand for these pears will increase when their real value becomes more generally recognized. It must also be borne in mind that, because of the great yielding capacity and the small cost of production, the grower may be making a fair profit even with very low prices ruling. If the grower is located near a cannery or a good local market, the chances of his getting good returns from these pears are greatly increased. Numerous growers living in the East have recently expressed themselves as being more willing to plant the hybrids than the common varieties. One thing appears to be fairly certain, however, and that is that these pears must be confined to the localities to which they are best suited; that is, where they may be grown at minimum cost and of maximum quality.

Moreover, greater care must be exercised in the matter of grading, packing, and marketing the fruit. The practice of sending the poor fruit along with the good, with little or no attempt at systematic grading, is very detrimental to the interests of the grower. In all cases the separation of the fruit into two or more grades will more than pay for the labor expended, and very often the better fruit, packed and sold alone, will bring better returns than the entire crop if packed without any grading. If the orchard is properly located and carefully managed, it will no doubt be a profitable piece of property.

Picking

The hybrids must be picked while green and ripened off the tree, in order to be of any commercial value. If they are allowed to remain

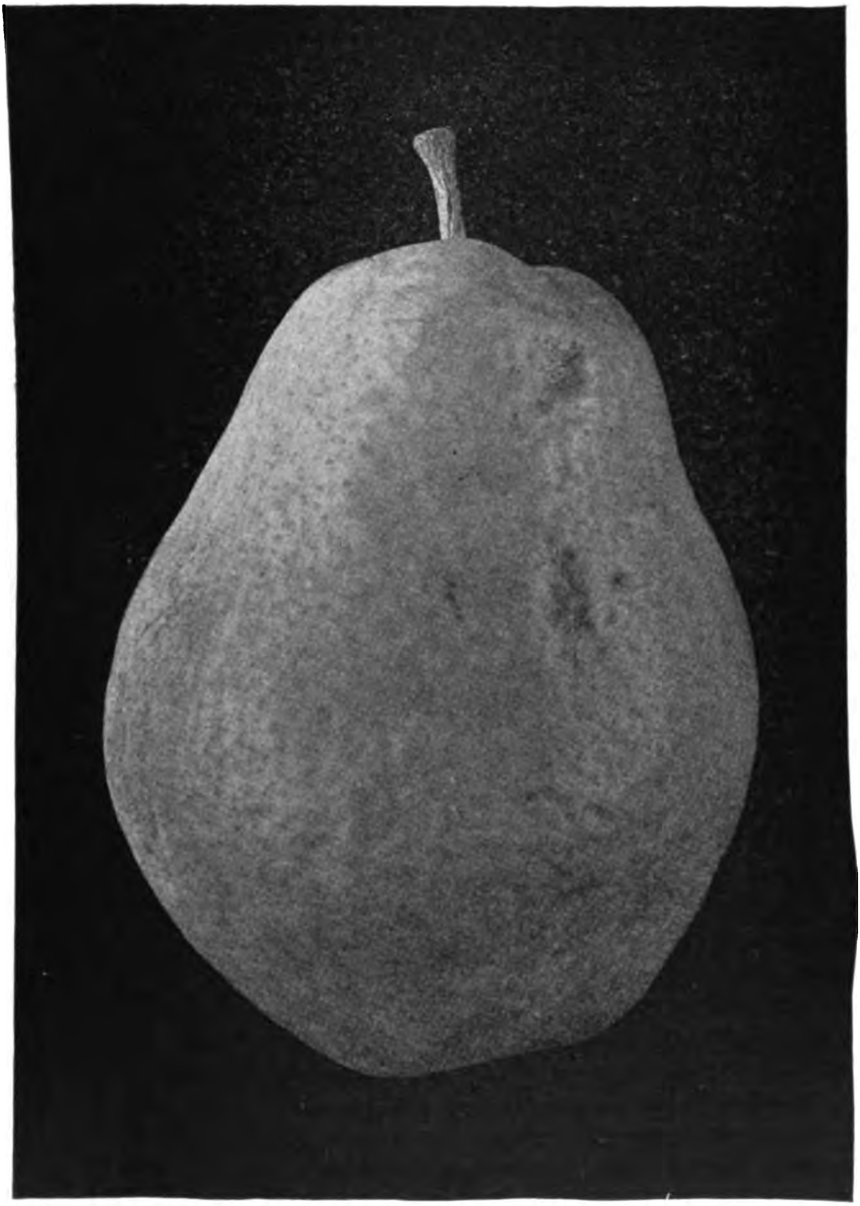

FIG. 153.— *Kieffer pear, natural size*

on the tree until fully ripe, the part around the core becomes a mass of hard, woody matter and the flesh is dry and mushy. But if the fruit is picked when it has reached full size, or even a little before, and is ripened in bulk, it becomes uniformly soft and juicy, with a flavor that almost warrants its being considered dessert fruit. The hybrids should be picked six to twelve days before they would ripen naturally on the tree, the date varying with the variety, season, temperature, and manner in which they are to be marketed. As a general rule, the change in color from a dead green to a clearer, lighter green, which is known to all pear-growers, indicates that the time for picking is at hand. Another indication is seen when, on the fruit's being taken hold of and gently lifted, the base of the stem parts fairly easily from the twig.

Varieties ripening in hot weather, such as Le Conte, should be picked at an earlier stage in the ripening process than should later-maturing ones, and southern fruit should be picked earlier than northern. It is often best, especially with summer varieties, to pick the trees over two or three times, although this is not necessary if the fruit has been properly thinned earlier in the season. But if the trees are bearing a very large crop, not only are they relieved of a heavy weight by an early picking, but also the fruit that is left swells to a much larger size.

There is an additional advantage in picking the hybrids in this manner, in that it lengthens the season and thus better enables the market to absorb the crop; so that by marketing the first picking immediately and putting the last picking in cellars or in common storage, the fruit can be marketed over a period of ten weeks without cold-storage. If it is intended that the crop be put in cold-storage, most growers place it there as soon as possible after harvesting.

Marketing

It is a source of wonder to many persons, as to where the large numbers of hybrids are consumed. A considerable percentage of them are used in the canning industry, which will be spoken of later. Southern Le Contes appear in the markets in early July, several weeks before the appearance of California Bartletts. While of medium quality at best, these early Le Contes are appreciated as the only available pears of the season and are used largely in cooking. They disappear from the market as soon as Bartlett, Clapp, and other summer pears come in. Southern Kieffers and northern Le Contes occupy the market until the northern Kieffer crop is picked, about the middle of September, and are on sale, together with other late pears, for the rest of the season. The hybrids possess an advantage over most of the common pears in being better able to stand transportation and rough handling.

The export trade for this fruit, although not very flourishing at present, seems to offer possibilities for the future. Shipments are made to Europe each year, their extent depending to a certain degree on the demand for them in our own markets. When the price is low in this country large shipments are made to English cities, which seem to be the best foreign markets for this fruit. The price that they bring there is dependent on the supply of all kinds of fruit on sale at the same time. The supply of French pears, especially, is an important factor in determining price.

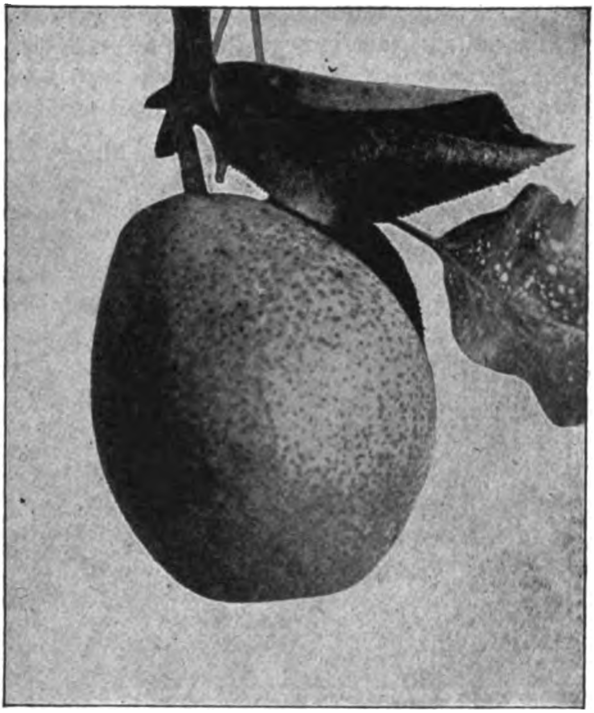

FIG. 154.— *Cincincis pear*

Cold-storage

Cold-storage has wrought a great change in the pear industry, as well as in that of all other kinds of fruit. The length of time that pears may be kept in cold-storage depends, in the first place, on the variety and its time of maturity. Kieffer and other hybrids may be held longer than the common kinds, and summer pears cannot be held so long a time as winter varieties. The hybrids can be kept in cold-storage as successfully as can most kinds of winter apples, if proper precautions are observed in handling them. The fruit should be stored as soon as possible after picking, since delay may cause it to become overripe after it is placed in the cold-storage house.

The best temperature for pears in storage is 32° F. if it is desired to hold them for a considerable length of time; but if it is intended to ripen them in storage, the temperature may be raised to 36° or 40° or even higher. Pears should be stored in packages from which heat will quickly radiate; fruit in tightly closed barrels will often become overripe before it has cooled down. Often such packages will contain in the center fruit that

has ripened much faster than that on the outside, which is more true of summer than of winter varieties. A paper wrapper around each pear will prolong its life by protecting it from bruising, lessening the tendency to wilt and decay, and keeping it bright in color, but this practice is not very common with the hybrids.

The air of the storage room should be kept fresh by proper ventilation.

It is best to place in cold-storage only the highest grades of fruit; that which is imperfect or bruised, or has been handled badly in any way, does not keep well and cannot be stored profitably.

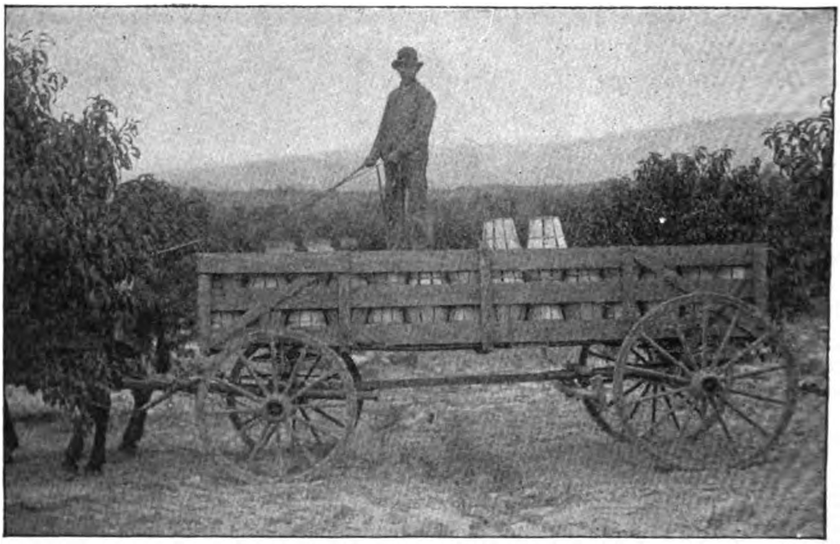

FIG. 155.— *The peach-basket is commonly used for Oriental pears in Maryland, Delaware, and New Jersey*

Packages

The packages used for pears vary widely in different regions of the country. The peach-basket is common for delivering the crop to canneries in Maryland, Delaware, and New Jersey. This usually goes under the name "five-eighths basket," but very few of the baskets contain as much as five eighths of a bushel. With a slat cover this basket is used also in shipping to market from the region named. In some respects it is the poorest of all packages, except where the grower can haul the fruit directly to his market or where a car can be filled by packing it tightly with these baskets. The half-barrel basket, or hamper, is sometimes used in this region, also the seven-eighths braced basket with cover.

The bushel box is used to some extent by growers of hybrid pears, but not so much as for the fancy grades of common pears. Another package is the barrel made especially for the pear trade, holding two and one fourth bushels; the regular apple barrel also is much in use. In some localities hybrid varieties are shipped in bulk by dealers, but this is a poor way and is almost sure to result in much damage to the fruit. It is well for the grower to consult the commission man in the market to which he expects to ship, in regard to the package most acceptable there.

Canning and evaporating

Although the quality of the hybrids at their best is only ordinary when used for dessert purposes, they are much improved if cooked. This fact has led to the building up of a large business in canning these pears. Before 1885 the canning of pears was of slight importance compared with that of other fruits and vegetables, partly because of the fact that Bartlett, the variety most used at that time for the purpose, ripens at a season when the canneries are running at their full capacity with peaches, tomatoes, and other products that require quick handling. To work with the Bartlett, therefore, would be at the expense of other equally perishable fruits and vegetables. The hybrids, however, and especially Kieffer, have many of the desirable canning qualities of the Bartlett and in addition an advantage as to season. Since Kieffer comes into the market after peaches and tomatoes have passed and can be held until December in common storage, the canneries can give it their entire attention and thus extend their season a month or two.

What becomes of the thousands of baskets of these pears that are sold to canneries is to some persons something of a mystery, since the word "Kieffer" is seldom seen on the cans. But when one realizes that practically every canning establishment has been canning Kieffer under the name of Bartlett or under no name at all, the wonder is not so great. It is said that up to the year 1900 only one firm in the country had the courage to put the name "Kieffer" on the cans of that variety. Surely this firm is entitled to great respect for its honesty and for the missionary work that it has done in raising this fruit in the popular esteem. Indeed, the hybrid varieties are in some respects superior to Bartlett for canning purposes. Bartletts do not hold their shape for so long a time as do the hybrids. It is of importance to note that the writer has been informed by a member of the Board of Food and Drug Inspection of the United States Department of Agriculture, that in his opinion the sale of Kieffer pears as Bartletts would be a deception and would be in violation of the Food and Drugs Act, although no case covering this point has yet been passed upon.

In regard to the extent of the industry, in 1899 there were 49,902,216 pounds of pears canned in the United States, valued at $2,233,166. The production of the five principal States in this respect was as follows:

State	Number of pounds	Value
California	32,329,128	$1,623,919
Maryland	6,911,424	181,358
New York	4,178,592	226,082
Delaware	2,621,464	62,361
New Jersey	1,760,496	63,356

Since the variety most used for this purpose in California is Bartlett, it is evident that at present Bartlett is in the lead. Furthermore, the average value per pound of the California product is about five cents, while that of Maryland, where the Kieffer is largely used, is only two and six tenths cents per pound. Although the demand for canned Kieffers seems to have weakened a little in the last few years, there is likely to be a fair call for them in the future. The fact that they can be produced at a lower cost than is the case with canned Bartlett will be a strong factor in maintaining the demand for Kieffer.

The evaporation of pears is a small business in this country, probably due to some extent to the fact that the shape of the pear does not lend itself to mechanical peeling and coring. The fruit is usually cut in halves or quarters and is either sun-dried or evaporated, with or without being peeled. In some cases it is subjected to a bleaching process. In 1899 there were 701,506 pounds of pears dried, valued at $49,279. Of this amount California produced 601,506 pounds, valued at $42,279, and Illinois 100,000 pounds, valued at $7,000. These were the only States reporting the industry as existing within their borders. The quantity of the hybrids evaporated, therefore, is very small, but there is no reason why they should not be as well adapted to this industry as are the common varieties.

CULTURE

Pruning

Of the four principal practices in orchard management — cultivating, spraying, fertilizing, and pruning — the first three are essentially the same for both the hybrids and the European pears. In the case of pruning, however, the problem is different. Whether the hybrids should be pruned to the pyramidal, vase-shaped, or natural form, is a question best determined by the personal preference of the grower. The young

hybrid tree that receives no systematic annual pruning sends up long, thin, willowy shoots. Fruit spurs fail to develop about the crowded bases of the shoots, but form on them far out from the trunk. When the tree begins to bear, therefore, as it does when rather young, the fruit, if not thinned, drags the branches out of their natural vertical position and often breaks them before the crop is matured. But if the branches of the young tree are kept well thinned, so that there is an abundance of light and air throughout the head, and if the new growth is cut back every winter to within ten or fifteen inches of the growth of the previous year, fruit spurs will be formed close to the trunk of the tree and the fruit will not bend nor break the branches. Thus a stocky growth is formed, which during the entire life of the tree will enable it much better to carry its heavy loads of fruit without breaking the limbs.

This practice of shortening the annual growth of the branches should be continued for the first six or eight years of the life of the tree, less severely, however, toward the end of this period, after which it will need no more attention in the way of pruning except the removal of diseased and interfering branches. By thus keeping the tree shapely and its growth within bounds, the operations of cultivating, spraying, and harvesting are greatly facilitated.

Propagating and dwarfing the hybrids

The Oriental pear and its hybrids may be propagated in five ways: (1) on its own roots by growing the trees from cuttings; (2) on Oriental seedling stocks by budding or grafting; (3) on common, or French, stocks; (4) on apple stocks; (5) on quince stocks. In the last-named case, dwarf trees are produced.

This type of pear, unlike most tree fruits, may be propagated from cuttings in much the same manner as are grapes or bush-fruits. Cuttings do not seem to root successfully, however, in any except a few favored localities, where the soil is deep and rich and the climate congenial. This method seems to be confined to the South, where a longer growing season makes the chances of success greater than in other regions. Where this method is a success, it is probably the cheapest and best way to obtain these trees. Even under the most favorable conditions, however, only a small percentage of the cuttings will be rooted, and twenty-five per cent is considered a good stand. Probably not a large number of these trees are grown by this method.

A few of the Oriental seedlings used as stocks are imported, but a large number are grown in this country, many of them from seed brought from Japan. The seedlings grown in the Western States on rich prairie soil make vigorous, healthy trees. Some nurserymen use them entirely as

stocks; they are reported as being better suited than are common stocks for the budding or grafting of the Orientals and the hybrids.

Imported French, or common, stocks, or the same stocks grown in this country, are used exclusively by many nurserymen. Whenever the Oriental pears or their hybrids, grafted on common stocks, are planted deep enough, roots start from the scions, and the number and strength of these roots is proportionate to the amount of the scion below ground. Thus, own-rooted trees are often obtained. Results of experiments conducted at the Texas Agricultural Experiment Station indicate that if the trees are not set deep enough for the scion to throw out root systems, they will be lacking in vigor and will die prematurely. It cannot be said that this has proved universally true in other localities, and as a rule French, or common, stocks seem to be fairly satisfactory. It would seem, however, that it is a safe plan to plant the trees sufficiently deep so that they can develop root systems of their own, partially or wholly.

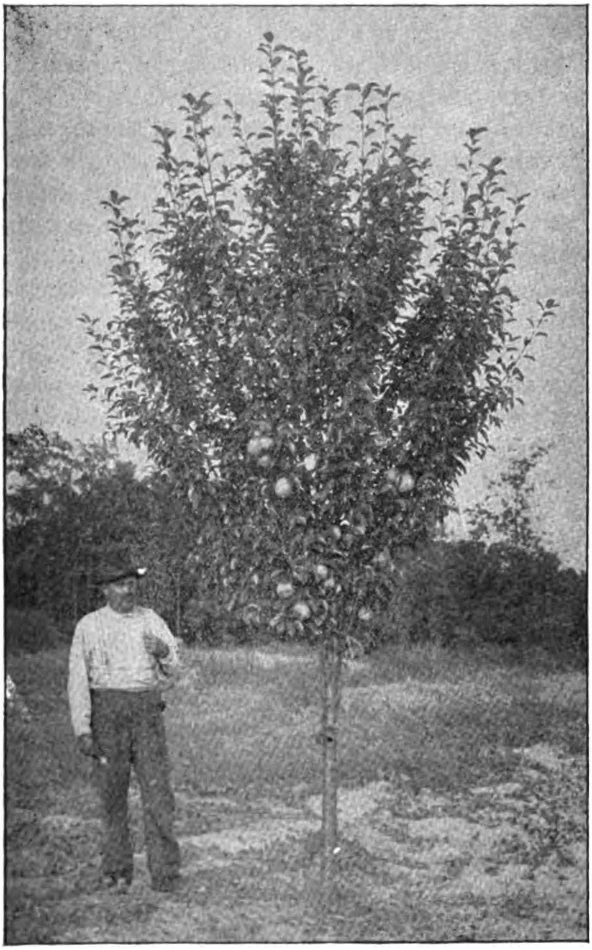

FIG. 156.— *Kieffer pear tree five years old, in South Carolina. Most of the fruit has already been picked from the tree*

Apple seedlings are used but little as stocks for Oriental varieties.

Although many varieties of the common pears do better when worked on quince than on common pears, it is generally admitted that pears of

the Oriental type and their hybrids are failures when grown as dwarfs. It is even believed by many practical horticulturists that if these pears are grown from buds or grafts taken from trees that had been grown on quince roots, they would be unsatisfactory. Nurserymen recognize this fact and very few hybrids are worked on quince roots.

Top-working the hybrids

The question as to whether or not these varieties can be top-worked to the common sorts is one of considerable importance and may become more important, especially to those growers who have planted the hybrids where they do not succeed well. The writer has corresponded with a large number of pear-growers concerning this subject and finds a considerable divergence of opinion. Although some growers report that they have done such top-working satisfactorily, a still larger number do not think favorably of the practice. It is often noted that the stock and scion do not make a perfect union, which is indicated by a restriction in the bark at the place where the graft was made. The scions grow normally for a few years, but when the tops become large and heavy they are likely to be snapped off during windstorms. There seems to be enough evidence to show that some varieties of the common pears can be top-grafted to the hybrids better than others. It is also probable that some of the hybrids are better suited for this purpose than others. Furthermore, it is probable that the reverse holds true of top-grafting the hybrids to the common varieties.

Later investigations.—"Further investigations have been made since the above was written. A large number of growers have found their Kieffer orchards unsatisfactory, and to them the possibility of top-working on other varieties is an interesting and important question. The general opinion at present seems to be that Kieffer cannot be reworked successfully. Some growers assert that scion and stock are uncongenial and that neither does well after union is made. Others say that the scion is forced to a vigorous growth when grafted on Kieffer, and thus becomes more susceptible to blight.

"In 1911 the writer sent out circular letters to a considerable number of pear-growers in New York State, asking them for their experience in top-working Kieffer. Answers were received from forty-six growers, and of these growers only thirteen had had experience in top-working Kieffer. The data obtained from these thirteen replies are tabulated in Table 1. From this it will be seen that only five recommend Kieffer as a stock, but eight say that the scions have been productive. Seven have top-worked Bartlett on Kieffer, and only one of these commends Kieffer as a stock. Seven have used Bosc, and three of these commend Kieffer as a stock.

" In Table 2 are tabulated the data obtained from a circular letter sent out in the spring of 1912, in continuation of this investigation, by

FIG. 157.— *Six-years-old Kieffer pear tree in bloom*

T. Sprague, Jr. Fifty-one of these circular letters were sent to growers in various parts of the country, including the States of Missouri, Iowa,

TABLE 1. EXPERIENCE OF THIRTEEN GROWERS IN TOP-WORKING KIEFFER. DATA COLLECTED IN 1911

Grower No.	Age at which Kieffer was top-worked (years)	Was Kieffer top-grafted or top-budded?	Varieties worked on Kieffer	Varieties that succeeded best	If union was not satisfactory, what was the reason?	Do you commend Kieffer as a stock?	Have trees been productive?	General remarks
1	4 to 5	Grafted	Seckel Bartlett	Neither	Were not congenial	No	No	Grafted trees all died
2	2 to 3	Grafted	Bosc		Good	Prefer Clapp's F.		
3	2	Grafted	Bartlett		Not congenial	No	Fairly so	
4	2	Grafted	Anjou Seckel Bosc	All equally well	Good	Yes	Very good for 18 years	Trees should be worked over gradually
5	2	Grafted	Le Conte	Le Conte	Good	Yes	Yes	
6	4	Grafted	Bosc Bartlett	Both equally well	Good	No	Yes	Scions blighted. Bosc worse than Bartlett
7	2 to 7	Grafted	Bosc	Bosc	Good	Yes	Yes	Grafting done by students of Conn. Agr. College
8	2	Grafted	Bosc Bartlett	Neither	Not congenial	No		Trees died
9	5 to 6	Budded	Bartlett		Good	No	Yes	Top made poor growth. Tree poor shape
10	5	Both	Bosc			No	No	
11	2	Budded	Bosc	Bosc	Good	Yes	Yes	
12		Grafted	Bartlett Winter Nelis		Good	Yes	Yes	
13	5	Grafted	Bartlett			No	No	Observations from a neighbor's trees

TABLE 2. EXPERIENCE OF NINE GROWERS IN TOP-WORKING KIEFFER. DATA COLLECTED IN 1912

Grower No.	Age at which Kieffer was top-worked (years)	Was Kieffer top-grafted or top-budded?	Varieties worked on Kieffer	Varieties that succeeded best	If union was not satisfactory, what was the reason?	Do you commend Kieffer as a stock?	What was effect of top-working on: Health of scion	Vigor of scion	Longevity of scion	Productivity of scion	General remarks
1	....	Grafted	Bartlett Winter Nelis Bosc	Bartlett Winter Nelis Bosc	....	Yes	....	....	....	Fair to good	
2	....	Grafted	Bartlett	Bartlett	....	Yes	Good	....	....	....	Grafting done 10 years ago. Very satisfactory
3	10 to 15	Both	Bartlett Seckel Orange	Seckel	Don't know	No	Good	Good first few years	Bartlett died after 3 years	Seckel satisfactory	Orange has been grafted only 3 years
4	6	Budded	Bartlett Bosc Seckel	None	....	No	All blighted	Vigorous	Have been budded 4 years	Not bearing	Few trees top-worked
5	4 to 5	Grafted	Bosc Seckel Anjou Bartlett Sheldon Howell	Seckel Bartlett Bosc	Swollen and weak-looking	No	Good	Good	Only 5 years old now	Not bearing	Blight, but not so bad as some trees of same variety
6	3	Grafted	Anjou Bosc Lawson	Anjou Bosc Lawson	Good	Anjou better	Good	Vigorous	20 years strong and good	Very productive	Only part of top should be worked at one time
7	1 to 10	Both	Bartlett Anjou Winter Nelis Bosc	None	Not congenial	Not for European varieties	Good first year	Good first year	Dead after 3 years	No fruit from European varieties	First year's growth abnormal
8	2	Grafted	100 or more varieties	Those most resistant to blight	Good	Yes	Poor	Good	....	Some varieties good	No one stock suitable for all varieties
9	1 to 10	Grafted	Bartlett Lawson Seckel Anjou	None	Good	No	Good	Poor	Nearly all dead	Lawson bears some	

Michigan, New Jersey, and New York. Thirty-three replies were received, but of these only twenty-five were from growers of Kieffer pears and only nine of the growers had had experience in top-working Kieffer. Three of the nine commend it as a stock, and five say that the scion has been productive. Seven have used Bartlett in top-working, and two of these commend Kieffer as a stock. Five have used Bosc, and only one of these commends Kieffer as a stock.

"In these two tables, wherever the age is given at which Kieffer was top-worked, with one exception all the men who commend it as a stock have used a two-years-old tree. This fact seems to signify that older trees may not be top-worked successfully.

"The opinions of the twenty-five growers of Kieffer replying to the circular letter of 1912 are about equally divided as to planting it as a commercial pear at the present time: fourteen growers would so plant it and eleven would not. Blight seems to be the only generally bad disease. Sixteen of the growers report blight in various degrees, while six say that the variety is susceptible to no diseases."— J. C.

SELF-STERILITY

In West Virginia and Michigan

The most comprehensive investigation of this question in reference to the Kieffer pear has been made by Dr. S. W. Fletcher, of the Virginia Agricultural Experiment Station, in orchards in West Virginia and Michigan. The experiments were at once extensive and exceedingly painstaking. Doctor Fletcher says that he was not able to discover in the crosses any constant difference in size, form, or color that could be attributed to the pollen used, "except that the self-pollinated fruits were very small." As results of three years work on self-sterility of the Kieffer pear, Doctor Fletcher gives the following averages:

1,268 blossoms Kieffer pollinated with Kieffer	gave	5	fruits, or 1 in	253
2,363 blossoms Kieffer pollinated with Bartlett	gave	446	fruits, or 1 in	5
448 blossoms Kieffer pollinated with Le Conte	gave	62	fruits, or 1 in	7
980 blossoms Kieffer pollinated with Lawrence	gave	173	fruits, or 1 in	6
2,764 blossoms Kieffer pollinated with Angouleme	gave	564	fruits, or 1 in	5
732 blossoms Kieffer pollinated with Anjou	gave	171	fruits, or 1 in	4
1,460 blossoms Kieffer pollinated with Clairgeau	gave	532	fruits, or 1 in	3
352 blossoms Kieffer pollinated with Garber	gave	51	fruits, or 1 in	7

When large trees of Kieffer were covered with muslin sheeting, so that pollen of other varieties was completely excluded, practically no fruit

FIG. 158.— *Kieffer orchard three years from planting, with windbreak of Russian mulberries at the right*

set, and such small specimens as did develop were without viable seeds. Doctor Fletcher concludes:*

" 1. In West Virginia and Michigan, and probably in other parts of the East, unsatisfactory results may be expected from planting either Bartlett or Kieffer in large blocks, so that cross-pollination by insects is not general.

" 2. Anjou, Lawrence, Duchess, and Kieffer, are satisfactory varieties for planting with Bartlett, so far as pollination is concerned. Some years Kieffer does not blossom simultaneously with Bartlett, but usually the blossoming seasons overlap sufficiently.

" 3. LeConte, Garber, Lawrence, Bartlett, Duchess, Anjou, and Clairgeau, are satisfactory varieties for planting with Kieffer, so far as pollination is concerned. Some years the latter five varieties do not blossom simultaneously with Kieffer, but usually their blossoming seasons overlap sufficiently."

" Fletcher's studies reveal the interesting observation that European varieties of pears are better pollinizers for Kieffer than are Le Conte or Garber, members of the Oriental group."— J. C.

In some other States

" The following communications describe clearly the present views and practices in the leading States where Oriental pears are grown."— J. C.

Maryland.— " The best practice in Maryland commercial orchards is to plant ninety per cent Kieffer and ten per cent Le Conte or Garber. Normally, Kieffer sets a good crop of fruit without cross-pollination, but it blooms at an early period when conditions are often unfavorable for pollination, and, having a tendency toward self-sterility, it seems advisable to plant it with other varieties.

" There is another point worth further investigation, and that is the tendency of fruit to grow larger when stimulated with pollen from certain other varieties. A rather striking case came to my attention this spring, in which Seckel pollinated with Anjou was noticeably larger than self-pollinated fruits."— W. R. Ballard.

Delaware.— " The practice of intermingling varieties of Oriental pears in planting varies considerably in Delaware. When pollinizers are used, the Garber is usually employed to pollinate Kieffers. (We are unable to grow Bartlett or other European pears with much success.) However, Kieffer orchards planted solid are common, and they seldom fail to set a full crop. My belief in the matter is that on the Delaware Peninsula the Kieffer is self-fertile under normal conditions. However, I have always advised the planting of pollinators in order to insure pollination

* Pollination of Bartlett and Kieffer pears. S. W. Fletcher. Reprint from Annual Report of the Virginia Agricultural Experiment Station, 1909–1910.

when conditions are adverse. If the trees are healthy, the weather is fair, and the bees are working at blossoming time, in my opinion mixing of varieties is unnecessary. However, as a matter of insurance, it would be best to have a few pollinators in the orchard. I think that you are right in regarding the problem as a local one."— C. A. McCue.

Blight a serious enemy in North Carolina.— " On account of the ravages of blight in the South, we are planting very few pear trees and of these only the Oriental varieties. This present season pear blight has been so bad that it has practically wiped out all neglected pear orchards and the disease has spread in the form of twig blight to a great many apple trees. For that reason pear-growing has practically become with us a dead letter.

" Regarding the pollination of Oriental pears, I have always found them to be very productive, showing that they were apparently sufficiently fertile with their own pollen. Where the blight does not affect them, the Kieffer and Le Conte will usually bear till they break the trees down with fruit."— W. N. Hutt, State Department of Agriculture, Raleigh, North Carolina.

ENEMIES

Insect pests

The following are the principal insect pests of pears: those injurious to the trunk are the pear-tree borer, scurfy bark louse, and San José scale; those injurious to the leaves are the pear-tree slug, blister mite, and pear-tree psylla; those injuring the fruit are the pear midge, codling moth, and plum curculio. In most regions the two last-named are the worst insect enemies of the fruit. Other insects of less importance are the round-headed and flat-headed apple-tree borers, oyster-shell bark louse, pear lecanium, and pear blight beetle. The leaves are liable to attack also from a great variety of caterpillars, which seldom do much damage.

Except in the case of San José scale, there is not enough evidence to show whether any of the above-mentioned insects are more or less injurious to Oriental pears than to common pears. Trees of the former type, however, have frequently been found free from scale, while varieties of European origin growing beside them have been almost entirely destroyed. Professor J. B. Smith, entomologist of the New Jersey experiment station, reports: " Kieffers alone are absolutely exempt, and, closely following, comes the Le Conte, which is rarely infested in the nursery and never, in my experience, in the orchard. One tree grafted with Lawson and Kieffer had the Lawson branch and fruit covered with scales, while the Kieffer branch was entirely free."* The Oriental pear is native to the countries where this insect has existed for centuries, and it is reasonable to expect

* Kieffer trees have been observed that were slightly infested with San José scale but not sufficiently infested to be seriously endangered.

its hybrid descendants to resist the pest better than can other species never before exposed to its attacks. Observers have reported that the scale has failed to establish itself on certain hybrid trees that have been repeatedly infested artificially. But, although it would seem that certain individual trees were immune, this cannot be maintained for the whole type. It will require more observation to arrive at an understanding of all the conditions that control this factor. While the Oriental hybrids, as a type, are not immune to the scale, certain trees seem to resist it very effectively. This points to a line of possible usefulness in breeding hybrid trees that are practically scale-free, by selecting buds and grafts from resistant trees.

Diseases

Fairly definite conclusions have been arrived at concerning the effect on the hybrids of two of the three principal diseases of pears, namely, scab and leaf blight. The evidence in regard to that worst of all pear diseases, fire blight, appears to be somewhat contradictory.

Scab.— Pear scab, which is caused by the fungus *Fusicladium pirinum*, is more destructive in the North than in the South, although it is still a serious disease as far south as Virginia. It rapidly diminishes in severity in regions south of that State. Scab is greatly affected by the weather in spring, being of little importance in dry, sunny weather, but causing much destruction in rainy, damp seasons. The disease attacks the blossom buds before the petals have opened, and new infections continue to take place especially while the fruit is small. After the fruit attains a diameter of an inch or more and the cuticle becomes somewhat firm, the more resistant sorts, especially the hybrids, become practically immune for the rest of the season; but the very thin-skinned varieties, such as Seckel, Flemish, and others, retain their susceptibility during most of the summer.

Leaf blight.— This disease, caused by the fungus *Entomosporium maculatum*, is unlike the scab in that it increases in virulence as one goes south. Although it does some damage in New York and New England, especially on nursery stock, it rarely becomes important north of the latitude of New Jersey. In Maryland, Virginia, and farther south it becomes the leading fungus on the pear. It produces small, circular spots on the leaves, causing them to fall from the tree by midsummer; and it produces a mottled appearance of the fruit, often causing the latter to develop on only one side and to crack open. The disease does most of its damage after warm weather begins and its work is most pronounced if the weather is very dry and hot.

Fire blight.— Often the trees most liable to blight and those most seriously injured by it are the most vigorous, the best cultivated, and the

best fertilized trees — in other words, those that are making a rapid growth of new, soft tissue. Climatic conditions influence the disease greatly; warm, moist weather with frequent rains favors it, while dry, sunny, and cool weather checks it partially or entirely. It is caused by a microbe that winters over in the orchard and is distributed in the spring by insects, which carry it to the blossoms. Less frequently the disease enters the tree where the bark is soft, through the agency of puncturing birds or insects, or where the bark has been injured. In the early days of the hybrid varieties it was thought that they were immune to this disease, but it was discovered later that this was not true. However, although many cases are reported in which the blight has been as destructive on the hybrids as on the common varieties, there is ample evidence to show that the hybrids have often been less affected than the latter class where the two were growing under similar conditions. What the controlling factor is in this matter, it is impossible to say at present. It may be that through careful selection a type of blight-proof hybrid pears will some day be produced, which will be of immense value to the pear-growing industry of this country.

VARIETY DESCRIPTIONS

The varieties of Oriental pears and the hybrids have many characters in common that distinguish them from European pears. Among themselves, however, the trees of the different varieties of the Oriental pear and the hybrids differ somewhat in manner of growth, in the size and autumn coloring of the leaves, and in the size, color, shape, flavor, and date of maturity of the fruit.

The Oriental pears have little resemblance to the pears of Europe. In color most kinds are of a dull greenish russet, with small yellow or russet dots; the skin is rough; in texture they are coarse-grained and watery, without much flavor or aroma. The hybrid varieties, however, have taken on many of the characters of the common sorts, although still retaining most of the indications of their Oriental ancestry.

A few of the hybrids are well known and readily recognized by pomologists, but the remainder of them, and practically all the unhybridized Oriental varieties, are but little known for the reason that they are planted to only a slight extent. It is rather difficult, therefore, to obtain accurate descriptions of many of them. The following descriptions have been compiled from notes made by many growers and nurserymen, but since they were made under varying conditions of climate and soil there has been some inconsistency among them. The best way to make a study of the comparative merits of these pears is to bring them together under uniform conditions, in much the same way that the Japanese plums have been studied at this station. It seems that some of the Oriental pears

are almost identical with others; indeed, some varieties are so similar that it is undoubtedly true there are more of them than are needed. This arises partly from the fact that many nurserymen, appreciating the value of some of their characters, have laid great stress on them and have brought forth a considerable number of "novelties" of this type. Although a large percentage of these Chinese and Japanese varieties are of practically no value, their many good points should and will be used in breeding better strains of the European pears. Already there have been workers in this field and the possibilities are indeed great. In writing the following descriptions much help has been obtained from the correspondence of Professor L. H. Bailey with various fruit-growers and nurserymen throughout the country, and from the notes of Professor John Craig. Systematic descriptions are, of course, not attempted here because of the meager information obtained regarding many of the varieties.

Cincincis.— Form fairly regular, oval; size medium to small; color light, with numerous brown dots; skin slightly roughened; cavity none; stem stout, one inch or more, much thickened; basin very shallow, wrinkled; calyx open in most specimens; flesh yellowish white, juicy; quality very poor, devoid of flavor; texture breaking, crisp; core large, gritty; seed large, flattish, black. Season, October. This variety resembles Sha Lea very closely. It is the parent of numerous seedlings fruited by S. F. Smith.

Cincincis Seedling.*— This variety was brought forward by William Parry and very closely resembles, if it is not identical with, Cincincis. Parry says of it: "Fruit medium to large, oblong, largest at stem end and tapering to blossom end, smooth, creamy yellow. Flesh tender, crisp, juicy, lacking quality."

Cincinnatus.— Another of the seedlings produced by S. F. Smith. Follette Smith, son of the originator, says: "The tree is vigorous, hardy, productive; fruit resembles Cincincis in color and shape, but is quite distinct in quality; juicy, subacid, rich; flesh gritty."

Commodore Perry.— Follette Smith says of this variety: "Tree vigorous, but with more of a dwarf habit of growth than Dewey's Premium, very productive. Fruit is oval, tapering toward the stem end, as large as Bartlett; color yellow, with red flush; quality good, free from grit. Season, last of September."

Conkleton.— A seedling of Le Conte from Texas. Tree said to be hardier and less subject to blight than its parent. Fruit much like Le Conte, but of better quality.

* The variety name as listed does not conform to the rules of nomenclature as adopted by the American Pomological Society. Since there is a variety called Cincincis and since the word "seedling" cannot be used as a variety name, the name "Cincincis Seedling" is used to distinguish this variety.

Conklin.— Fruit fairly large, oblate, obtuse pyriform; skin greenish or pale yellow, netted and patched with russet, dotted with green or brown dots; stem medium, fleshy at insertion; calyx partially enclosed in a deep basin; flesh yellowish, coarse, juicy, half-melting, sweet, fairly good quality. Season, September. The variety originated in Westchester county, New York.

FIG. 159.— *Conklin pear*

Daimyo.— This variety closely resembles Mikado. It is said that its flesh is dry and lacking in the aromatic flavor of Siebold.

"Daimyo.— Introduced by Simon Louis Frères, 1873. Collected by von Siebold in Japan. Fruit large, spherical ovoid; stem very long, recurved, fleshy, lower part the same color as fruit; calyx large, open; flowers large; color olive green, sometimes with marbling on the surface; flesh white; fruit perfumed with cydonia-like odor. Uneatable in natural state; good for cooking. Simon Louis Frères."— J. C.

Dewey.— Form conical to roundish oval, resembling Kieffer; size medium; color rusty green with faint flush; skin rough; cavity broad, shallow, ridged, and irregular; stem stout, straight, incurved, two inches long; basin very small, irregular, russeted; calyx open, calyx lobes long; flesh white, juicy; quality poor; texture coarse, gritty, fibrous; core large, open, surrounded by grit; seeds long, brownish black; fruit variable in size and form. Season, last of October.

Dodge *Hybrid.*— Form ovate, pyriform, narrowing rapidly to the stem; size medium; color greenish yellow, profusely dotted; skin thin but tough, russeted near stem; basin medium size, slightly wrinkled; stem stout, straight; cavity none; calyx open, medium size; flesh white, juicy;

quality fair, not rich; texture melting, tender, no grittiness; core small; seed good size, plump. Season, early October. Very similar in appearance to Virgalieu.

Duchesse Hybrid.— Form resembles Kieffer; color lemon-yellow; flesh coarse; quality poor. Season, October.

Farragut.— A seedling of Cincincis originated by S. F. Smith, of Marietta, Ohio. The writer has not found it listed in any of the nursery catalogues. This was one of the seedlings that were sent by Mr. Smith to D. M. Dewey, with the request that he name them and have plates made of them. From the sketch thus made this variety appears to be

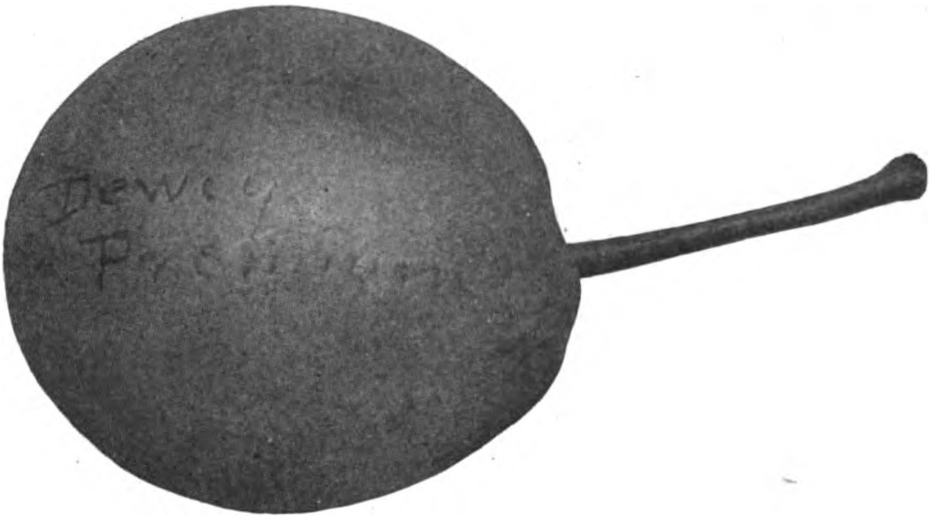

FIG. 160.— *Dewey pear*

large, of the same shape as Bartlett, and greenish with a red flush. Mr. Dewey says that the flesh is melting, juicy, fine-grained, subacid, and pleasant. Season, last of September.

Garber.— In some sections of the lower Mississippi Valley this is considered the best of the hybrids, one reason being that it blooms late and hence escapes late frosts. In quality the fruit is probably a little better than Kieffer, but the tree does not come to bearing at quite so early an age. Form of fruit oval, truncate at both ends; size large, three to four inches in diameter; color light yellow, with pink flush; skin smooth, slightly greasy; cavity large; stem slender, one and one fourth inch long; basin small, usually narrow and circular; calyx generally open, segments long; flesh white, juicy; quality insipid, subacid, lacking in sweetness; texture crisp, not melting; core small, closed, surrounded by grit; seeds small, black, sharply pointed. Season, late fall.

Gibb.— Raised from seed sent by Charles Gibb from Mongolia to Professor Budd at Ames, Iowa, and named by the latter. It is said to be very hardy and productive, coming into bearing when rather young. Fruit about the size of Bartlett; shape pyriform; nearly equal to Bartlett in quality, according to Professor Budd. This variety and the other seedlings of the same origin seem to be of a decidedly better quality than the rest of the Oriental pears and are of a different type, although they all probably belong to the same species.

FIG. 161.— *Dodge pear*

Gold Dust.— Fruit of Bergamot shape, with slender stem; skin very rough. Season, October. Probably resembles Golden Russet very closely.

Golden Russet.— This is said to closely resemble Gold Dust, Hubbard *Japan*, and Japan Wonder. Form apple-shaped, rather flat, regular; size medium; color light lemon-yellow, with many fine dots, russeted especially about the stem; skin roughish; cavity shallow; stem about two inches long, slender; calyx present; flesh juicy, aromatic, slightly sweetish; quality very poor; texture coarse. Season, October. Tree very hardy and a young bearer, often blossoming the first year and setting fruit the second.

Hawaii.— Form apple-shaped; size medium; color light lemon-yellow, with rough, russet dots; cavity rather shallow; stem long, slender, and

curved; basin shallow; flesh hard, gritty; flavor poor, subacid. Season, October. "Sandwich Island" is a synonym for this variety.

Hubbard *Japan*.— Form apple-shaped; size fairly large; color yellow, with russet dots; flesh white, brittle; quality no better than most of the others of this type. Resembles Japan Wonder and Golden Russet. Introduced by Dr. J. T. Whitaker, of Tyler, Texas.

Japan Wonder.— Another introduction by Doctor Whitaker, who says

FIG. 162.— *Golden Russet*

of it: "The fruit is rather flat, large, apple-like; color light yellow, with many white dots covering the entire surface; flesh white, brittle, juicy, poor in quality. Tree an open grower."

Japanese Sand.— Said to be similar to Hawaii. Form apple-shaped; size medium; color lemon-yellow, with russet dots; cavity shallow; stem long, slender, and straight; basin shallow; flesh hard; quality poor; flavor much like Daimyo. Season, late October.

Kieffer.— Fruit roundish oval, narrowing at both ends, with the greater diameter near the center; size medium to large; color yellow, orange-

yellow in the sun, with light red flush; skin smooth, with many brown russet dots; cavity small, narrow; stem stout, straight, swollen at base, length short to medium; basin small, corrugated, russeted; calyx large, usually open, segments curved; flesh melting, yellowish white, juicy; quality fair when ripened off tree; texture lacks sprightliness; core large, open, surrounded by line of grit; seed medium in size, black. Season, last of September. Tree hardy, vigorous, and productive, like its Oriental relatives.

Le Conte.— Form regular, oval to oblong; size medium to large; color yellow, often with touch of red on sunny side; skin smooth, rarely subject to scab; cavity none; stem short, stout; basin narrow, shallow; flesh white, tender, very juicy; flavor sweetish, perfumed, subacid; quality poor to ordinary, scarcely as good as Kieffer; core medium size, surrounded by line of grit. Season, July in South, to middle September in North. Tree vigorous and productive, coming to bearing at about five years of age; color of the young wood almost pear green. In some parts of the South, especially in Texas, the fruit buds are often killed by late frosts. The northern range of this variety is not so extensive as that of Kieffer.

Magnolia.— Fruit large, roundish to pyriform; surface smooth; color yellowish russet, with numerous irregular dots; flesh white, crisp, tender, juicy, mild, subacid; quality fair. Tree is rather dwarfish. Season, three or four weeks later than Kieffer in the South. Origin, south Georgia.

Marietta.— Tree is said to be inclined to grow tall with a single main stem; fruit light yellow with red blush. Season, October.

Mikado.— Form roundish, apple-shaped; size medium; color lemon-yellow, with russet dots; skin rather rough; cavity almost wanting; stem long, slender, and bent; basin shallow; flesh white, slightly aromatic; quality poor; flavor subacid; texture coarse, brittle. Season, last of September.

"Mikado.— Fruit rather large, spherical-ovoid; peduncle very long, recurved, half black and half greenish; eye large, open, not sunk; skin rough to the touch, yellowish olive, dotted with gray specks and marbled with mildew on the surface; flesh white, fine, brittle, rather juicy, perfumed, with a pronounced quince flavor, uneatable raw. Simon Louis Frères."— J. C.

Mongolian.— Fruit medium to large, roundish oval, narrowing at both ends, with its greatest diameter near the middle, similar to Kieffer in shape, inclined to ridging near the apex; color greenish, with blushed cheeks and russet dots; stem an inch long or more, stout, set in broad, shallow cavity raised on one side, giving the stem an inclination; basin deep, ridged; flesh tender, melting, juicy. Professor Budd considers it the best of the Oriental varieties yet tested in this country. Obtained from seed at Ames, Iowa.

Sha Lea *Chinese Sand*.— The name "Chinese Sand" was used as a varietal name by the pomologists of fifty years ago, but it is doubtful whether they meant to use it except as the name of the type. In recent years, however, a few nurserymen have listed this as the name of a variety. Downing says of it: "The fruit is of medium size, roundish pyriform, dull yellow, covered with a rough, sandy-like russet. Flesh firm, moderately juicy, cooks well, and acquires a fine flavor. September."

Siebold.— Flesh aromatic and juicy. This variety is probably somewhat similar to Mikado. "Madame von Siebold" and "Sieboldii" are synonyms for this variety.

"The following description was made on the grounds of Simon Louis Frères, Metz."— J. C.

"Madame von Siebold.— Fruit very large, rounded, a little narrow toward the cavity, where it is angular; truncated at the base and indented at the circumference. Peduncle long, thick at the joining, rather large, inserted in a rather deep cavity, widened and wrinkled at the edges. Eye large, half closed; cavity not very deep, but rather wide. Skin rather smooth, of a pretty brown color, dotted with large gray specks which are very regular and very apparent. Flesh white, slightly yellowish, medium fine, crisp, juicy, sweet, perfumed like quinces, almost eatable raw. The most beautiful of the Japanese. Simon Louis Frères."— J. C.

"Sieboldii.— Medium to large pyriform with elongated tendency, angled and irregular; stem long and larger than ordinary; calyx open; cavity deep and large; color slightly red on sunny side, grayish in shade; flesh white, breaking, sweet, perfumed; cannot be eaten raw with pleasure. Simon Louis Frères."— J. C.

Sikaya.— Form oblate, regular; size medium to small; color buff, russeted; skin tough, almost covered with large russet dots; cavity small, regular; stem long, stout at base; basin small, shallow; calyx large, with open lobes resting on side of basin; flesh yellowish white, coarse; quality poor, insipid, subacid; texture melting, gritty; core medium, open, lined with grit; seed flattened, black. Season late.

Smith.—Form oval, truncate at basin end; size medium to large; color yellowish green; skin smooth, with patches of russet occasionally; cavity none; stem straight, much thickened at base; basin small, shallow, slightly wrinkled; calyx prominent, open; flesh white, firm; quality poor, insipid, dry; texture mealy; core small; seed flat, almost black. Season, October. This variety is very similar to Le Conte, but blooms later, thus producing a more certain crop.

Smith Beauty.— Similar to Le Conte, but with no blush; shorter than Dewey; calyx well developed. Variety name has been listed as **"Smith's Winter Beauty."**

Strong.— Description lacking. Variety name has been listed as "Strong's Japan."

Suet Lea.— Form apple-shaped to oblong, regular; size medium to small; color light yellow, with large, rough, russet dots; cavity medium, fairly regular; stem long, thick at base; basin shallow, small, corrugated; calyx deciduous; flesh greenish white, lacking juice, hard, and gritty; quality poor; texture crisp, breaking; core large, open; seed large, black. Season late.

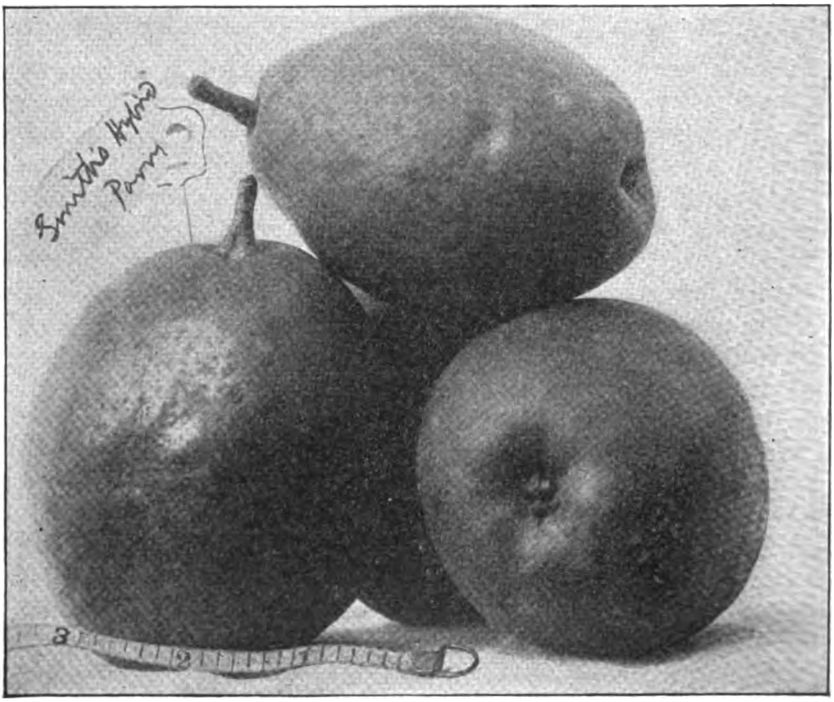

FIG. 163.— *Smith*

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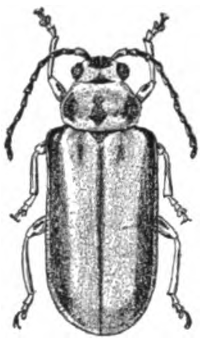
CONTROL OF TWO ELM-TREE PESTS



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CONTROL OF TWO ELM-TREE PESTS

GLENN W. HERRICK

THE ELM LEAF-BEETLE

(*Galerucella luteola* Müll.)

The American elm is perhaps the greatest favorite among shade trees in the United States. It is probably more widely planted for this purpose than any other tree, especially in the eastern part of the country. Our forefathers in New England, remembering their beloved English elms, went into the woods, brought forth the slender, graceful young elms, and set them in front of their homes and along their streets. As their descendants marched westward they too remembered these fine trees and followed the commendable example of their fathers. The fine trunk of the elm, with its spreading branches terminating in graceful, pendulous tips, makes it a very beautiful tree. There is no street more attractive than an avenue almost arched with the mighty arms of the elms.

It is a source of great regret that the American elm is subject to the attacks of a most injurious insect pest, the imported elm leaf-beetle. But fortunately this pest can be controlled if fought with vigor and thoroughness.

The imported elm leaf-beetle was abundant and injurious in Baltimore, Maryland, in 1838. It must have come into the country about 1834. Since that time it has gradually extended its territory until now it is found as far north as Massachusetts and New York and as far west as Ohio and Kentucky. In New York State it is destructive in the eastern and central sections and will probably extend its activity gradually until it covers the greater part of the State.

Professor Slingerland[1] records the appearance of the beetle in Ithaca for the first time in 1902. A student in Cornell University, P. B. Powell, discovered the eggshells and the young and nearly mature grubs on July 13, 1902, on some elms along University Avenue, which leads to the Cornell University campus. Apparently the infestation was light, for only a few branches on a dozen trees were found affected. On July 16 beetles were found, and on August 2 the beetles emerged from larvæ collected earlier. The beetles must soon have invaded the trees on the university campus, and from that time until the spring of 1911 they steadily increased in numbers and destructiveness. By 1911 the trees had begun to show seriously the effects of the injury and a few had nearly succumbed. It

[1] Entomological News, vol. 14, 1903, p. 30.

is doubtful whether some of them will recover. Several English elms, which are more subject to injury from this beetle than are American elms, had to be cut down. A part of the injury to these trees, however, was caused by the elm leaf-miner.

The condition of the trees in 1910 was such that it became imperative to take preventive measures before another season should pass. Accord-

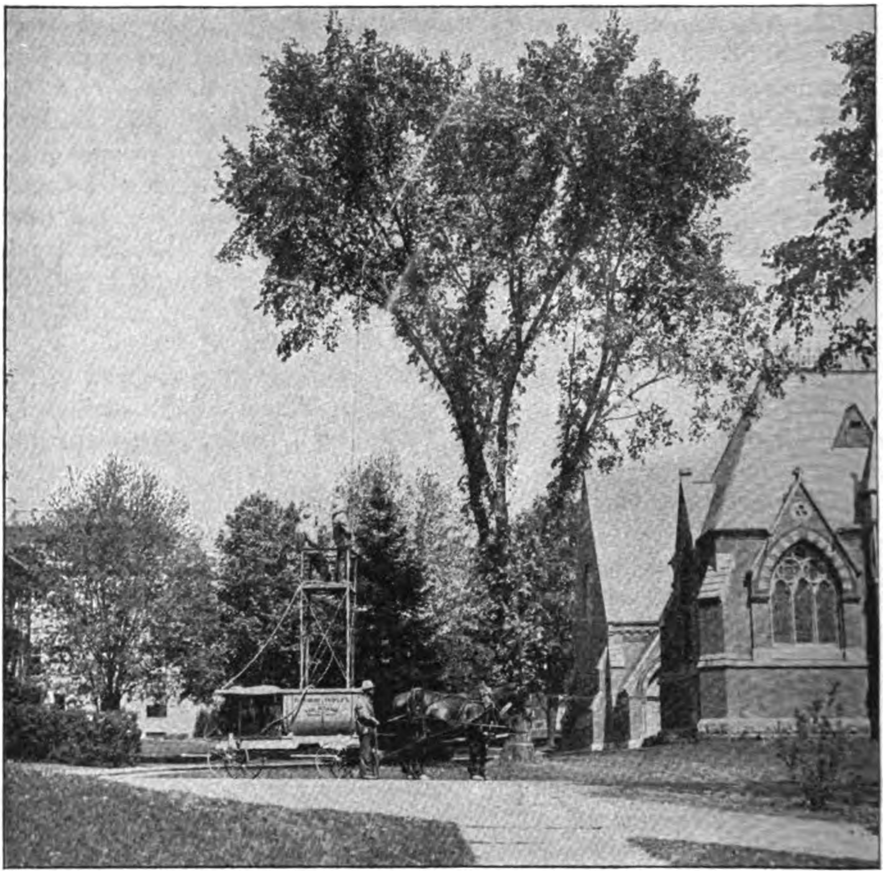


FIG. 164.— *Spraying a high elm with a Hardie machine*

ingly, the Board of Trustees of Cornell University made a liberal appropriation for spraying the elms on the university grounds, and preparation for the work was at once begun. The problem seemed a rather large one. However, the spraying has now been carried through two seasons, and, while nothing startling has been developed in the way of new methods or apparatus, the work has proved to be practical, economical, and efficient.

SPRAYING APPARATUS

The first question which presented itself was that of the apparatus to be used. It was necessary to procure machines that were not expensive. Moreover, many of the trees were on steep hillsides and were difficult to reach, so that the type of heavy machines used in work with the gipsy moth did not seem suited to the present problem. Again, there were

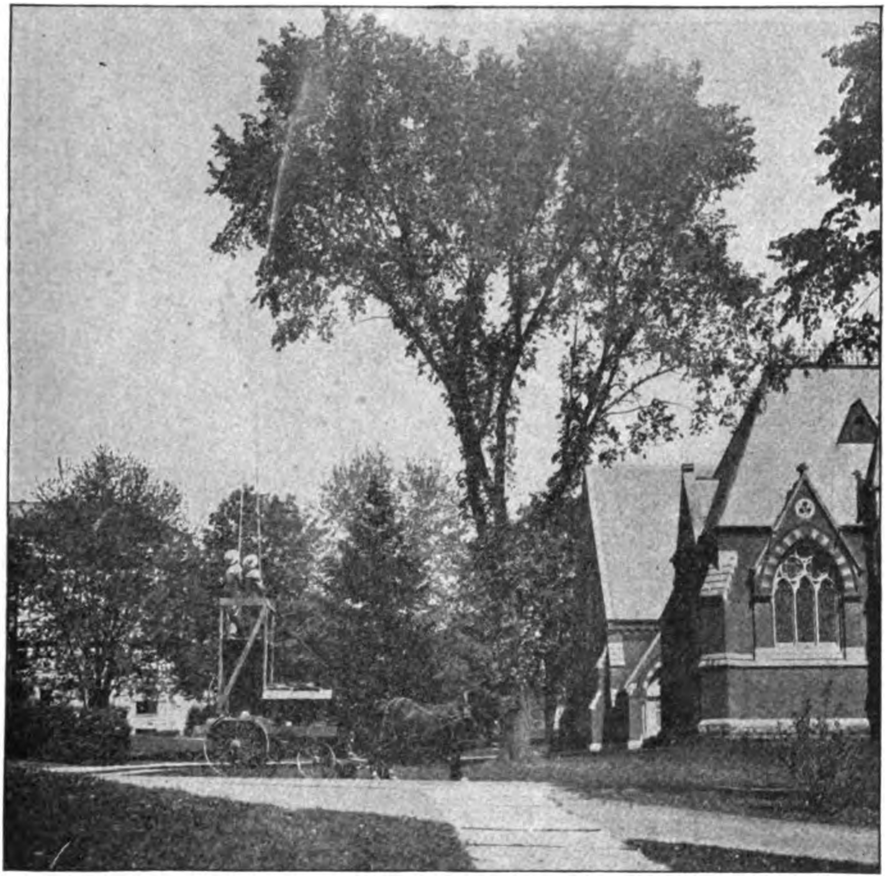


FIG. 165.— *Spraying a high elm with a Friend machine*

comparatively few trees and it seemed unwise to spend a thousand dollars or more for a very large machine. It was necessary, however, to have a machine that would maintain a high pressure in order to force a stream to the tops of the trees.

After a thorough consideration of all the points involved, it was decided that two power spraying machines of the following specifications should

be bought: (1) A Hardie Eastern Triplex power sprayer with 200-gallon tank; a triplex pump with 2½-inch cylinders; a vertical 3-horsepower Ideal engine; two lines of ½-inch hose, each 100 feet long; a 12-foot tower; two extension poles, one 20 feet and the other 12 feet long. (2) A Friend Hilly-orchard Model power sprayer with 200-gallon tank; a large-size California model pump; a 3½-horsepower engine; an 8-foot tower; and other equipment the same as for the first-named machine. Each of these

FIG. 166.— *Spraying from tower and from ground*

machines was mounted on a truck ready for the field. The price of the Hardie machine is $274 f. o. b. Hudson, Michigan; that of the heavy Friend machine is $300 f. o. b. Gasport, New York. At all times it was possible to maintain 200 pounds pressure with either outfit, and both machines gave satisfactory results.

Bordeaux nozzles were used for all the work because these are adjustable. A solid stream could be thrown to the tops of the high trees, or a fine spray could be used for the lower limbs.

One man was stationed on the tower with the 20-foot extension rod. When he desired to change from a solid stream to a mist spray he merely lowered the nozzle to a man on the ground, who changed the adjustment of the nozzle. The man on the ground sprayed the lower branches, looked after the engine, and drove the team. An extra man was present, the so-called foreman, who directed the work, mixed the solutions, attended to breakdowns, climbed trees if necessary, and was generally responsible for the spraying operations.

There is one rather serious fault to be found with the long extension poles or with any of the common extension poles. The brass conducting pipe on the pole is too small in diameter to carry enough liquid and, besides, it greatly reduces the pressure at the nozzle. If a conducting pipe of larger diameter could be made of a lighter material that would stand the pressure, it would be advantageous. Much more liquid could be thrown; the spraying could be done faster, and thus a larger amount of space covered in a given time. Moreover, because of the pressure's not being lessened, the stream could be thrown higher. For the short poles, pieces of quarter-inch gas pipe 12 feet long were substituted in the work here described and these gave better satisfaction. Longer pieces of pipe than this, however, would be too heavy.

Smaller spraying machines

Low and medium-sized trees may be sprayed with fair efficiency with a hand-spraying outfit, such as is shown in Fig. 167. This consists of a barrel mounted on a two-wheeled cart for convenience in moving from tree to tree. A strong hand-pump is fitted into the barrel. With such an outfit a pressure of 75 pounds can be maintained, although this requires rather strenuous work on the part of the man who does the pumping. In connection with this barrel pump a tall, firm step-ladder is needed, also a piece of hose 50 feet long fitted to an extension rod 10 or 12 feet long. With an outfit of this kind, fairly large and tall trees may be sprayed efficiently and economically.

FIG. 167.—*Hand-spraying outfit*

High-power spraying machines[1]

In the crusade in New England against the gipsy and brown-tail moths, great improvements have been made in spraying outfits for forest and shade trees. The machines have been made much heavier and the engines are of high horsepower, so that solid streams are thrown to the tops of the highest trees from a nozzle held by a man on the ground (Fig. 168). This has greatly simplified the work of spraying forest and shade trees. Lines of hose 200 or 300 feet in length are laid along the ground, leading from the machine. In this manner trees on either side of the road, for a considerable distance back from the fences, may be sprayed without the machine's leaving the highway. Such machines cost about $1,000 and are rather expensive for most of the work with shade trees. However, they furnish almost an ideal method of spraying trees. With a high-power machine of this type it is not necessary to have a tower or to climb trees.

The large machines used in the work with gipsy moths have triplex pumps and 8- or 10-horsepower engines. The two- and four-cycle engines have been used, the latter apparently having given the better satisfaction. Lately the two-cylinder marine-motor type of engine has been tried and has proved very satisfactory. With these machines either 1½-inch or 1-inch hose is used, the latter being preferable. The nozzle is of much the same type as that used on fire hose.

SPRAYING OPERATIONS

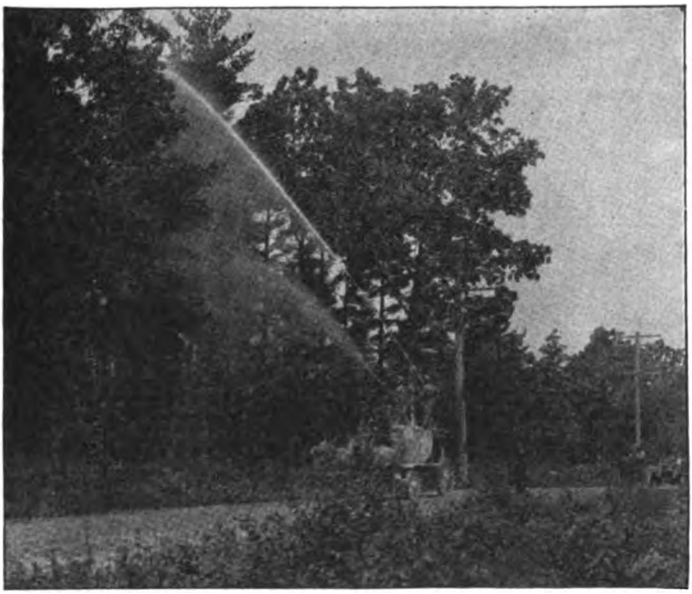
In 1911 the first spraying was begun on May 16. This application was made just as soon as the trees were in good leaf, although not in full leaf. The adult, over-wintering beetles became active at least as early as May 2. They had been observed on the windowpanes of houses for some time previous to this date, therefore they must have left their hibernating places several days before. On May 11 the elms were rapidly coming into leaf. The beetles were on the trees and were eating ravenously on those trees that were well in leaf. The work was delayed, however, until the following Monday, May 16, in order that more of the trees might come into fuller leaf.

In 1912 the season was considerably later and spraying for the beetles was not begun until June 13. The trees were well in leaf by May 27, however, for on May 27 and 28 spraying for the elm leaf-miner was done. There was a difference of about ten days between the two seasons. In 1912 the beetles were first noted on the trees on May 17. By May 21 they were abundant and were eating ravenously.

[1] Bulletin 87, Bureau of Entomology, United States Department of Agriculture, pp. 64–67.

PHOTOGRAPH BY C. R. CROSBY

FIG. 168.— *Spraying trees from the ground with high-power machines in Massachusetts*



PHOTOGRAPH BY C. R. CROSBY

FIG. 169.— *Spraying trees with high-power machines in Massachusetts*

Paste arsenate of lead was used for the most part, at the rate of 3 pounds to 50 gallons of water for the first application. For the second application the proportion was 3½ pounds to 50 gallons of water. On about thirty-five trees powdered arsenate of lead was used, at the rate of 1½ pounds to 50 gallons of water.

In all there were on the university grounds about five hundred and thirty trees that were sprayed in 1911. About one hundred of these were scattered over the steep hillsides west of the buildings and along University and Stewart avenues. Many of the trees were nearly a mile from the campus water supply, and the majority were scattered and not easy to reach. Exclusive of permanent equipment, the cost of spraying these trees twice was $464.90, or an average of approximately 88 cents each. The scattered trees raised materially the average cost of the whole. If all the trees had stood along streets and reasonably near a water supply, the average cost, the writer thinks, would have fallen below 70 cents. With the two machines it took ten days to make the first spraying and eleven days to make the second. The second spraying was done more thoroughly and there was much more leaf surface to be covered; on the other hand, experience had made the men more efficient. The great majority of the trees were over forty years old, while some were older; nearly all of them were large.

DETAILS OF COST OF SPRAYING ELMS ON CORNELL UNIVERSITY CAMPUS[1]

In order to give a clear idea of the cost of spraying elm trees, a few details of the work on different days are here presented. The men were paid $2 a day with the exception of the foreman, who was an experienced man and who received $5 a day. The men who drove the teams and sprayed the trees were inexperienced. The amount paid for teams was $2 a day.

On June 20 the two machines sprayed eighty-two trees, some of which were small. The total expense of this day, including men, teams, arsenate of lead, and gasoline, was $24.91, an average of 30⅜ cents per tree. On June 16 sixty-six trees were sprayed at a total cost of $22.14, an average of 33½ cents per tree; these were all large trees. On June 19 fifty-nine of the largest trees on the campus were sprayed — those along Central Avenue southward from the Library. The cost of spraying these trees was $23.965, an average of 40⅝ cents per tree. These trees stood close to the street and near a water supply. They are very large trees, having a great amount of leaf surface. This should give one a fair idea as to the cost of spraying the largest trees.

[1] Journal of Economic Entomology, vol. 5, no. 2, April, 1912, pp. 170–171.

FIG. 170.— *English elms killed by leaf-beetles and -miners*

FIG. 171.— *English elms sprayed and recovering from attacks of beetles and miners*

A careful and detailed record was kept of the actual cost of spraying four hundred and thirty-five trees. Most of these trees were large and all stood near the street and near the campus water supply. The cost of spraying these trees once was $133.37, or 30.7 cents per tree. On the average, each machine sprayed 36¼ trees per day of eight hours, or 4½ trees per hour, or a single tree about every 13⅓ minutes. The average quantity of liquid used for each tree was approximately 18⅙ gallons. With the bordeaux nozzle, or with any nozzle throwing a coarse stream, considerable liquid is sure to be wasted. Nevertheless, the writer thinks it is not wise to try to be too economical in the use of the spraying material. Both the upper and undersides of the foliage should be covered, even if some material goes to waste in getting about among the branches.

During the season of 1912 the beetles were not so abundant nor so injurious. They appeared considerably later in the spring than in 1911. No beetles were seen on the trees until May 17 and they were not abundant until May 22. Spraying was begun on June 13 and finished on June 22. This was a little later than usual, it having been decided to spray but once because of the scarcity of beetles and because of the thorough spraying in the preceding year. It cost $218.90 to spray the trees in 1912, an average of 41⅓ cents per tree. Since only one application was given, the work was done somewhat more thoroughly than before and considerably more liquid was used. The men on the towers were paid $2.50 a day, an advance of 50 cents over the amount paid in 1911.

Powdered arsenate of lead, at the rate of 1½ pounds to 50 gallons of water, was used on one hundred and twenty-six trees. It gave as good results in controlling the beetles as did the paste, and mixed a little more readily with water. It was slightly more expensive than the paste.

COST OF SPRAYING SHADE TREES IN OTHER LOCALITIES

It has been shown that in the work at Cornell University the cost of spraying each tree was about 30 to 41 cents when one application was given. It is probably safe to say that the shade trees of most towns and cities could be efficiently sprayed at this cost. It must be remembered that the trees on the Cornell University campus were being sprayed by an entomologist who was anxious that the work should be an unqualified success, at least so far as controlling the beetle was concerned. Great pains were taken to coat all parts of the trees, especially the topmost and the inner branches. In order to do thorough, careful work, much time and material must be consumed. Undoubtedly the trees were more thoroughly sprayed than are average trees. It would be easy to cut the cost of spraying one fourth or one third by slighting the work.

The trees on Cornell Heights in the city of Ithaca, New York, were sprayed in 1912 by contract at 22½ cents each. These trees, which are not very large, range from 20 to 30 feet in height. Individual trees in the city of Ithaca are sprayed, by contract for the season, at a cost ranging from $1 to $2 per tree, depending on size, distance from water supply, and other conditions. It often becomes necessary, in the case of these individual trees, to use special care in order to prevent the spraying material from being sprinkled on the houses. Moreover, many of the trees in Ithaca are very large, and all such trees must be climbed in order to reach the top.

Some figures showing the cost of spraying elm trees are given by Dr. E. P. Felt.[1] He reports Dr. J. B. Smith as saying that the elms on the college campus at New Brunswick, New Jersey, were sprayed at odd times by the janitors. It took two men, with a force-pump and ladders, about one hour to spray a single tree. Including the poison used, the cost was about 56 cents per tree. In the city of New Brunswick the trees were sprayed at a contract price of $1, it being understood that they were to receive three treatments if necessary.

Considerable data are given by Mr. Kirkland,[2] of Massachusetts, on the cost of spraying trees, mostly woodland trees. In general the cost is 20 to 45 cents each for spraying trees averaging 35 to 60 feet in height.

Doctor Felt states that the trees in Albany, which present a wide range in size, were sprayed during the season of 1898 at the low cost of 15 cents per tree. He reports later[3] that the trees in Lansingburg, New York, were sprayed at a cost price to the contractor of about 23 cents, while in Troy the same contractor charged 50 to 60 cents for individual trees here and there throughout the city.

In Albany the trees were sprayed in 1901 at an average cost of 22 cents each when 5 pounds of Bowker's disparene to 100 gallons of water was used. The average number of trees sprayed each day by each outfit was forty.

The city of Saratoga Springs sprayed its maple trees in 1900 at an average cost of 17½ cents per tree. These trees were sprayed for the forest tent-caterpillar, and the spraying did not require so much time and material as would have been needed for the elm leaf-beetle.

PROPER TIME FOR SPRAYING

The first spraying should be done just as soon as the leaves are three fourths grown or larger, and as soon as the characteristic feeding-holes

[1] Bulletin 20, New York State Museum, 1898, p. 22.
[2] Third Annual Report of Superintendent for Suppressing the Gipsy and Brown tail Moths, 1908, pp. 140–159.
[3] Seventeenth Report New York State Entomologist, 1901, p. 739.

of the beetles appear. The beetles come from their winter hibernating places in early spring as the leaves are beginning to push out, and in a few days they begin to eat holes in the leaves (Fig. 172). *This is the time when the first spraying should be done.*

This time will vary with the earliness or lateness of the season. In 1911 the first spraying was begun on May 16, while in 1912 spraying was not begun until June 13. This, however, was a few days later than the work would have been begun had it been purposed to make two applications. In making the first application no particular attention need be paid to coating the undersides of the leaves, since the beetles eat holes entirely through the foliage.

FIG. 172.—*Adult beetles eating leaf in spring*

The second spraying should be done as the eggs begin to hatch, which will be about three weeks after the first application. In 1911 the second spraying was begun nearly four weeks after the first, but probably it should have been begun somewhat earlier. In making this application special pains should be taken to coat the undersides of the leaves. The grubs of the beetle work on the lower sides of the leaves almost entirely, and in order to kill the insects before they have done serious injury the poison should be on the underside.

The first injury noticed by the grubs is likely to be in the tops of the trees, although the grubs have been seen seemingly as abundant and injurious on the lower branches as higher up. Nevertheless, the writer would emphasize the importance of reaching the topmost branches with the spray. If a few grubs are left in these branches they will eventually transform and furnish a crop of adult beetles for succeeding years.

The writer would also emphasize the necessity of spraying early for beetles and for grubs. If the beetles or a large percentage of them are killed, not many eggs will be deposited; while the grubs are much more easily killed when young than when two thirds or three fourths grown.

AMOUNT OF POISON TO USE AND NUMBER OF TIMES TO SPRAY

As already stated, the trees were sprayed twice during the first season of the work and the mixture used was 3 pounds and $3\frac{1}{2}$ pounds, respectively, of paste arsenate of lead to 50 gallons of water. The brand of arsenate

of lead used contained about 15 per cent arsenic oxid. When powdered arsenate of lead was used, the proportion was 1½ pound to 50 gallons of water.

Other experimenters recommend the use of 4 pounds of paste arsenate of lead to 50 gallons of water. A. F. Burgess, who has had much experience in combating the gipsy moth and the elm leaf-beetle, says that "the cheapest and most satisfactory remedy for the gipsy moth and the elm leaf-beetle consists in thoroughly spraying the trees with arsenate of lead, using 10 pounds to 100 gallons of water, as early in the spring as there is sufficient foliage to hold the poison." Mr. Burgess's aim is to use a large amount of arsenate of lead and to spray but once. The writer thinks this is a good practice to follow after one year of thorough work. If the elms in a town or city have been neglected and allowed to suffer for several seasons from the ravages of the beetle, the writer thinks it would be desirable to give two sprayings the first season of treatment, using in each application 3 to 3½ pounds of poison to 50 gallons of water. Thereafter, probably one thorough spraying after the leaves are fairly well out, using 4 to 5 pounds of arsenate of lead to 50 gallons of water, would suffice. That practice has been followed and has satisfactorily controlled the beetle.

To summarize, it would seem that 3 to 5 pounds of arsenate of lead to 50 gallons of water, with two applications the first year of the fight and one thereafter, are sufficient.

LIFE HISTORY AND HABITS OF THE ELM LEAF-BEETLE

Appearance and work of the beetle

The insect is about one fourth of an inch long. In general it is yellowish or brownish yellow in color, with a dark line along each side of its back. Its color varies somewhat, and the over-wintering beetles are often so dark-colored that the brownish yellow almost disappears and the dark lines are hardly noticeable. In its normal coloring it is quite likely to be confused with the common striped cucumber beetle, although it is considerably larger.

When the beetle first awakens in the spring from its long winter sleep it flies to the elm trees just bursting into leaf and takes its first meal by eating small, irregular holes through the young, tender leaves (Fig. 172).

Story of its life

In the fall of the year many of the full-grown beetles, when searching for snug crannies in which to pass the winter, find their way into dwelling-houses, congregating especially in attics where they are often found by

the score. Housekeepers are sometimes alarmed when they see so many of these beetles crawling on their windowpanes, walls, and ceilings, thinking that probably here is another household pest. Fortunately, so far as the writer is aware, these insects do not injure household articles of any description. Other individuals hide under loose pieces of bark on trees, in cracks in fences and telegraph poles, in outhouses, sheds, and any other sheltered places that they are able to find. Here they remain in a quiet, inactive condition through the long winter months. With the warm days of spring the beetles awake and begin crawling about on the walks and on the windowpanes.

As soon as the leaves of the elm begin to appear the insects fly to the trees for their first spring meal. After feeding for some time they deposit their conspicuous orange-colored eggs (Fig. 173) in clusters of five to twenty-five on the undersides of the leaves. The egg is flask-shaped, and stands upright with its larger end attached to the leaf. The eggs hatch in five or six days during hot weather, but in cool weather this period may be prolonged several days. The grubs eat ravenously, increase rapidly in size, and complete their growth in fifteen to twenty days. When full-grown they either crawl down the trunk of the tree or drop from the ends of the branches. At the bases of the trunks many of the larvæ transform into the yellow pupæ (Fig. 176). Sometimes they are so numerous that the pupæ lie an inch deep about the foot of the tree. Other larvæ undergo transformation in crevices of the bark, especially if the trunk of the tree is rough; others go to gutters; while still others seek shelter in crevices of the sidewalk and wherever they can find hiding-places. The quiet, inactive pupæ lie motionless for six to ten days and then transform into adult beetles, thus completing the life round of one generation.

Observations on the life cycle and number of generations at Ithaca

During the last week in April in 1911 the beetles became active and were especially evident on the windowpanes of dwelling-houses. By May 2 the elm trees were blooming and the leaf buds were beginning to show green. By May 11 the trees were beginning to come into leaf rapidly and some were fairly well in leaf. The beetles were present at this time on the leaves and were eating ravenously. On May 16 eggs were found on the leaves; they were probably deposited a few days earlier. On May 18 eggs were found in some abundance on the English elms. On May 22 the first eggs were hatching; during the succeeding two weeks the eggs were hatching in abundance. By June 18 a few larvæ were found pupating, and from that time into the first week in July

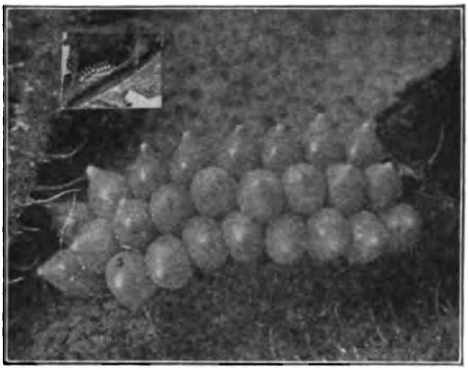


FIG. 173.— *Eggs, natural size, and much enlarged*

FIG. 174.— *Young grubs eating leaf*

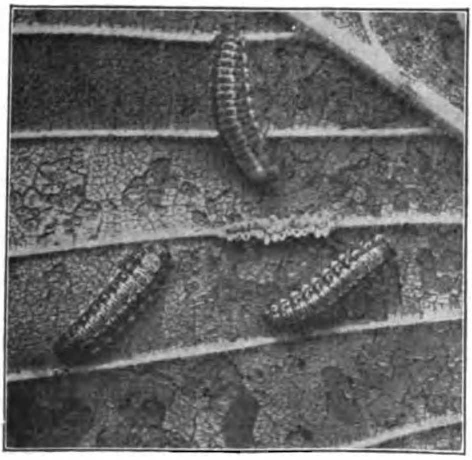


FIG. 175.— *Grubs nearly grown*

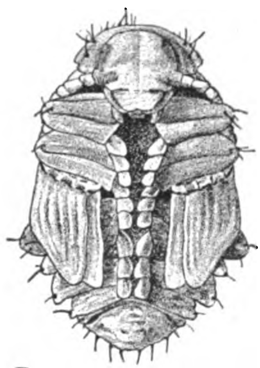


FIG. 176.— *Pupa of the elm leaf-beetle*

[Figures 173, 174, 175, 177, 180, and 181 are from photographs by the late M. V. Slingerland.]

the larvæ pupated in abundance. Several adult beetles were observed emerging from scores of pupæ at the bases of trees on July 8.

On July 17 many beetles were noted on the leaves of the elms, but no eggs were found. On July 20, however, H. H. Knight discovered a bunch of twelve eggs that had been deposited by a beetle found in the field on July 8. This beetle had been confined in a cage in the insectary. On July 27 and July 30 Mr. Knight found an abundance of eggs of the second brood on some English elms in the city of Ithaca. Some of these eggs were already hatching, which showed that they had been deposited several days earlier. By the first week in August the eggs of the second brood were hatching in abundance. The English elms, on which the eggs were found, had been practically defoliated by the first brood, not having been sprayed; these trees had put forth a growth of new leaves. By September 1 many larvæ had left the trees and a few pupæ were found at the bases of the English elms. Most of the pupæ of this second brood were destroyed by the fungus *Sporotrichum globuliferum*. It is possible that there is a partial third brood in Ithaca in favorable seasons, such as that of 1911, for example. The history of the beetle was not followed in detail further than the first week in September during that season, but in the latter part of September the writer noted what were apparently nearly full-grown larvæ on elm leaves. These were possibly the larvæ of the third brood.

Doctor Felt[1] has noted a partial third generation under favorable conditions in the vicinity of Troy and Albany.

In 1912 the conditions were very different from those in 1911, for the beetles appeared much later in the season. In fact, they appeared so late that it was thought they were not coming in any abundance and would do no great harm. They came late in the season, however, and did considerable damage where no spraying was done.

In 1910 the writer stated, " Our observations show that in Ithaca we have one generation, with a possible second, the latter, however, being so small as to cause no serious damage."[2] The observations on which this statement was founded were made in 1910. The season of 1910 was similar to that of 1912, in which the beetles appeared late. In 1910 and 1912 the second generation was apparently small and did little damage, especially on the American elms where these observations were made. This is a fair illustration of the absurdity of drawing general conclusions and deducing general principles regarding the activities of an insect, from observations carried on during only one season. Moreover, it would seem that these insects, at least in Ithaca, are much more

[1] Bulletin 20, New York State Museum, 1898, p. 13.
[2] Circular No. 8, Cornell University Agricultural Experiment Station, 1910, p. 4.

abundant on English elms and that they pass through their life cycle somewhat faster on these trees than on American elms. Therefore, observations confined to individuals occurring on American elms might lead to conclusions concerning the rapidity of development and number of broods different from those resulting if individuals occurring on English elms were observed.

THE ELM LEAF-MINER

(*Kaliosysphinga ulmi* Sund.)

The Scotch and English elms and the Camperdown elms are subject to the attacks of the larva of a small sawfly, which mines the tissues of the leaves. Up to 1911 no adequate or effective method of control of this miner had been found, so far as the writer is aware.

CONTROL MEASURES

Recalling the penetrating power of certain contact insecticides, it occurred to the writer that possibly the larvæ might be killed in their mines in the leaves before they caused much injury. It was with a rather forlorn hope, however, that a fine, small Scotch elm, which had been badly injured by miners in previous years, was sprayed in the spring of 1911.[1]

FIG. 177.— *The European elm sawfly, much enlarged*

The material applied consisted of "Black-leaf 40" tobacco extract, diluted at the rate of 1 pint to 100 gallons of water, with 9 pounds of laundry soap dissolved and added to the mixture. It was the intention to use but 8 pounds of soap to 100 gallons of the mixture, but by mistake 9 pounds was added. The application was made in May, 1911, just as the tiny mines had begun to show in the leaves. The effect was certainly surprising. Many of the sprayed leaves were examined during the succeeding few days and every larva was found dead. Each one had evidently been killed at once, the mines on the sprayed leaves not having been perceptibly enlarged. The contrast later in the season between the topmost branches, which could not be reached, and the lower branches was very marked (Figs. 178 and 179). The leaves not sprayed were almost completely mined and became withered and most unsightly.

In 1912 these experiments were repeated on a much larger scale, there being several English elms on the university campus that had been badly injured for several years. A row of such elms extends along a stone wall bordering University Avenue. These trees were set by the founder of the University, Ezra Cornell. They had suffered severely from attacks of the leaf-beetle and the miner. Some of them had been so badly injured that they had been cut out, while those remaining bore many

[1] Journal of Economic Entomology, vol. 5, no. 2, April, 1912, p. 172.]

dead branches and were in a weak, dying condition. These trees were sprayed thoroughly with "Black-leaf" tobacco extract, 3 gallons to 200 gallons of water, with 10 pounds of fish-oil soap and 8 pounds of arsenate of lead. "Black-leaf" tobacco extract contains only 2.7 per cent nicotine and is usually diluted at the rate of 1 gallon to 70 or 80 gallons of water. In these experiments the mixture was slightly stronger than this, because of the necessity of thorough work.

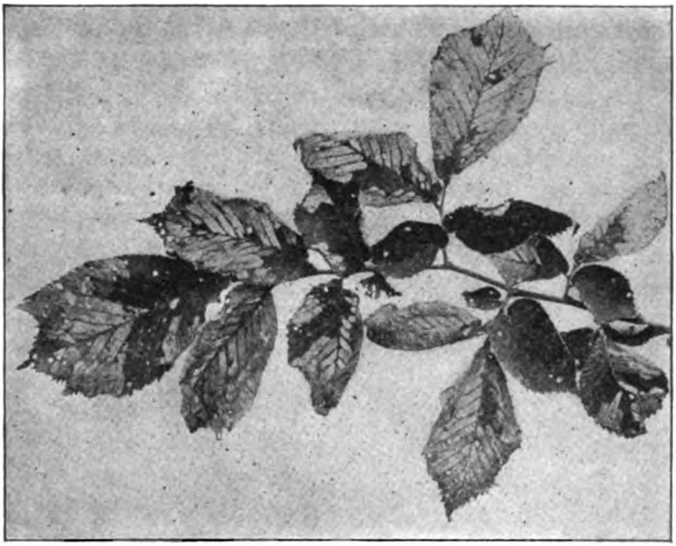


FIG. 178.— *Unsprayed leaves infested with the miner*

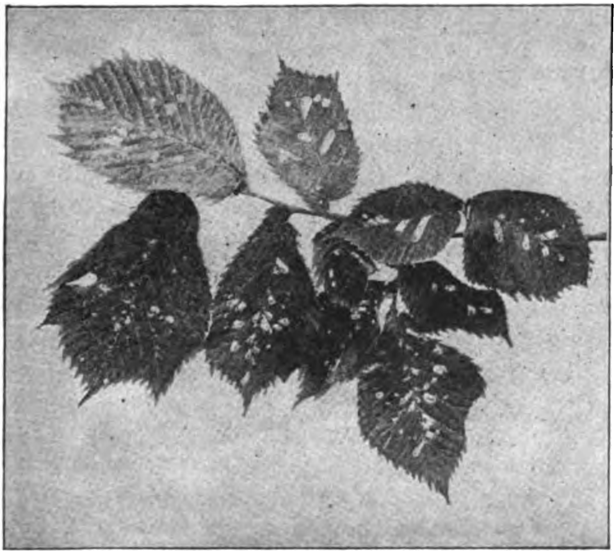


FIG. 179.— *Sprayed leaves from the same tree*

Owing to difficulty with the pump and the engine there was a delay of a day or two in getting to these trees, and some of the larger larvæ were not killed so soon as had been expected. The tobacco must have worked on them slowly, however, for the trees made better growth than they had before in some years, and looked in the fall

as though they had taken a new hold on life (Fig. 171). A row of the same kind of trees of about the same age, not far from these, nearly all died during the summer and were cut down (Fig. 170). It is evident that the "Black-leaf" extract does not work so fast as does the "Black-leaf 40."

Eight other trees were sprayed on May 28 with "Black-leaf 40" (which contains 40 per cent nicotine), at the rate of 1 pint to 100 gallons of water, with 5 pounds of fish-oil soap and 3 pounds of powdered arsenate of lead added. These trees, which had been badly injured by the miner in preceding seasons, were in good condition at the end of this season. All the young miners and many of the older ones were killed at once in their mines. Here and there, where the leaves had not been thoroughly coated with the mixture, some of the larvæ that were larger and older at the time of spraying escaped.

One Camperdown elm was sprayed thoroughly. It was low and the leaves could be coated thoroughly on both sides. The miners were completely held in check on this tree.

On the whole, the work showed that this pest of the European elms can be held in check if taken at the proper time. The trees must be sprayed early, *just as soon as the tiny mines begin to show in the leaves.*

The "Black-leaf 40," 1 pint to 100 gallons of water with 5 pounds of soap, seems to be more effective than the "Black-leaf." One great advantage of these tobacco extracts is that the arsenate of lead may be added for the leaf-beetle, thus obviating the necessity of a separate spraying for each insect.

It might be well to say that "Black-leaf 40" is a tobacco extract manufactured by the Kentucky Tobacco Product Company, Louisville, Kentucky. It may be bought from that firm direct, or it may be procured from several distributing agents in the State. It is sold by the Leadley Drug Company, Batavia, the Rex Company, Rochester, and the Parsons Drug Company, Albion. The price is $12.50 per gallon or $1.85 per pint. When it is diluted at the rate of 1 pint to 100 gallons of water, however, it costs no more than lime-sulfur or other contact insecticides.

LIFE HISTORY OF THE ELM LEAF-MINER

The adult insect is a small, shining black sawfly about one eighth of an inch in length. The wings expand about one third of an inch. In the latter part of May the sawflies may be seen on the leaves of the elm. They are not shy and can often be picked up with the fingers.

The tiny, milk-white eggs are thrust by the female into the tissues of the leaf from the upper side. They hatch in about one week and the

young larvæ begin their mines at once. The majority of the eggs are probably deposited, in most seasons, in the middle of May.

The larvæ grow rapidly, and by July 1 all have practically completed their growth and gone into the ground under the tree. Here they burrow downward an inch or less and soon make a thin, brown, papery cocoon in which they hibernate until the next May. Apparently they pass the winter as larvæ, changing into pupæ in the spring. Thus there is but one brood a year.

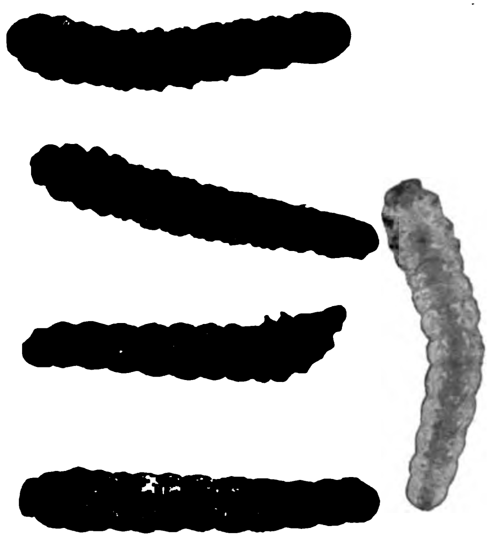


FIG. 180.— *Larvæ of elm leaf-miner, much enlarged*

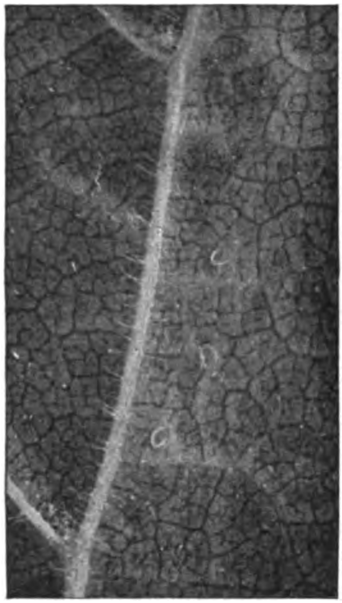


FIG. 181.— *Three eggs of elm leaf-miner stuck in leaf. Much enlarged*

NATURE OF INJURIES CAUSED BY THE ELM LEAF-MINER

The work of this miner becomes very conspicuous in June. The leaves become blotched and blistered by the mines of the larvæ. Several miners usually attack a single leaf and their mines eventually coalesce and form large, whitish blisters (Fig. 178). Often the inner tissues of nearly the whole leaf are mined out, forming a blister over the entire area of the leaf. The leaves then wither and turn brown and the tree looks as though it had been scorched by fire. Unless the leaves are wholly mined they remain on the tree. Small trees are often almost defoliated, especially small Camperdown elms. A half dozen small English elms standing in a group on the campus have been most seriously injured for several seasons.

JUDICIOUS PLANTING AS AN AID IN THE CONTROL OF THESE PESTS

In view of the wide and serious injury to shade trees by many different insects, it becomes pertinent to discuss some general princi-les of control of such pests. In the first place, it is unwise to depend almost entirely on one species of tree for shade or ornament. The very existence of the American elm, for example, in the eastern United States at least, is threatened by two serious pests, the elm leaf-beetle and the leopard moth. Probably the elm leaf-beetle could be controlled if every owner of elm trees would spray. It is quite probable that the leopard moth cannot be controlled and that eventually the elms will succumb to these two pests. The trees have already disappeared from the Harvard Yard as a result of the ravages of these insects. The sugar maples are becoming more and more subject to serious injuries from borers. Many fine trees are dying each year and there seems to be no help for the situation. The graceful white birches are going one by one as a result of the ravages of the bronze birch borer, while the hickories are hard beset by the hickory bark-borer.

With these facts in mind, it is important to give careful and thoughtful consideration of the question of the wise selection and planting of shade trees. A city in which the streets are planted only to elms and maples is likely to be without shade trees in the near future. The wide planting of one kind of tree over considerable territory forms ideal conditions for the increase and spread of an extended outbreak of an injurious species of insect. On the other hand, if adjacent streets are planted to different varieties of shade trees an outbreak of any single pest can be checked and controlled much more easily. Elms and maples can well be supplanted in many cases by oaks, especially the pin oak and the red oak, or by the ginkgo tree — a handsome but rather slow-growing tree, and one remarkably free from pests. The Norway maples make fine shade trees, and so do the linden, the horse-chestnut, and the American ash.

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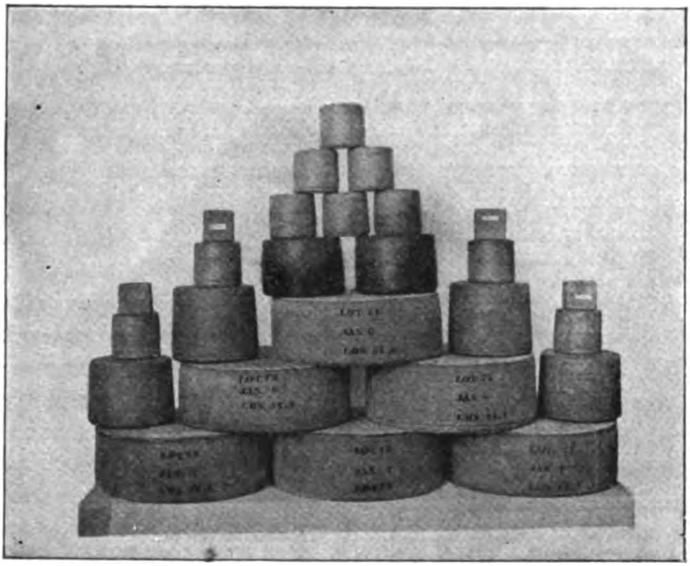
CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Dairy Industry

A STUDY OF SOME FACTORS INFLUENCING THE YIELD AND THE MOISTURE CONTENT OF CHEDDAR CHEESE



BY W. W. FISK

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AGRICULTURAL EXPERIMENT STATION

Experimenting Staff

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A STUDY OF SOME FACTORS INFLUENCING THE YIELD AND THE MOISTURE CONTENT OF CHEDDAR CHEESE

W. W. Fisk

(*Received for publication April 1, 1913*)

In order to make cheddar cheese of good quality, the cheese-maker must maintain the proper relationship between the amount of acid and the amount of moisture in the cheese. If too much moisture is present it will cause the cheese to be soft and weak-bodied. An excess of moisture is likely also to cause cheese to "shelf-sour," owing to the large amount of milk sugar present in the whey. Since the whey is retained as moisture this milk sugar gradually changes to lactic acid, due to the action of the bacteria present. If, on the other hand, a sufficient amount of moisture is not present, the cheese becomes hard and dry in texture and requires a much longer time in which to ripen. In order to obtain the best cheese possible a proper relationship must exist between the acidity and the moisture. After the rennet extract is added, the cheese-maker practically loses his control of the acidity but he can watch its development with various acid tests. The cheese-maker must now direct his efforts toward maintaining the proper amount of moisture for the amount of acid present. In order to do this the cheese-maker must use skill; as there are no quick methods of determining the amount of moisture in the curd, he must rely on the special senses, sight and smell and touch. There are certain practices, common with cheese-makers, which they believe will increase or decrease the amount of moisture in cheese.

It is the object of this study to determine which of these practices increase and which decrease the amount of moisture retained in the cheese, and to what extent such practices increase or decrease the moisture. Some of the factors studied are within the control of the cheese-maker and some are not.

PLAN OF INVESTIGATION AND METHOD OF PROCEDURE

It was planned to make cheese under various well-defined conditions; to keep record of each step of the process; to keep record of the losses of fat in the whey; to weigh the cheese when taken from the hoop and again after being cured; to compute the yield; and to make moisture determinations of the green and of the cured cheese.

For this work a twin vat was used whenever possible, in order that the same temperature might be maintained in each vat. In the study of some factors, however, it was not possible to use the twin vat, and in that

case two small vats were used. This will be noted in the discussion of each experiment.

The milk used was mixed herd milk delivered to the college cheese factory by its patrons. This milk was run into a large vat and ripened to the desired acidity; an equal amount was then placed in each of the small vats. The milk in the large vat was stirred continuously while the small vats were being filled, in order that the milk in each vat should contain the same percentage of fat. The sample of milk to be tested for fat was taken while the milk was flowing from the large vat. The sample of whey to be tested for fat was taken in three parts while the whey was being removed from the vat. All determinations of acid were made by direct titrations with an acid test. In case there were no drippings from the vat, the hot iron test was used. The temperatures were taken with an ordinary floating dairy thermometer that had been tested with a standard thermometer; one of these floating thermometers was placed in each vat.

The time, acidity, and temperature of each step of the work were carefully recorded on a lot card similar to the one shown below. One of these cards was entirely filled out with each vat. This was an easy method of filing the results of the experiment, and when the moisture determinations were made they were placed on the backs of the cards so that all the data from each vat and each cheese were on a single card. The next morning after the cheeses were made, they were taken from the hoops, weighed, and placed in the curing rooms, where they were held at about atmospheric temperatures.

NEW YORK STATE COLLEGE
OF AGRICULTURE
AT CORNELL UNIVERSITY

DEPARTMENT OF
DAIRY INDUSTRY

21 **CHEESE** This card must remain with lot..............................from the milk room until the finished product is ready to leave the building, then it should be handed to instructor.

MAKING Day and date.. Vat......................

Milk Used..............................	....	**Milk**
....	....	Appearance of milk..............................
....	....	Odor..............................
		Taste..............................
		Weather conditions..............................
Total pounds		**Starter**
................per cent fat	................lbs. fat	Kind used..............................
................per cent solids not fat	............lbs. solids not fat	Flavor..............................
		Acidity..............................
...........per cent casein	...........lbs. casein	Amount used........ Percentage used.......

Time of	Minutes
adding starter...	....
adding rennet....	....
coagulation......	....
cutting..........	....
turning on steam.	....
turning off steam.	....
dipping..........	....
packing..........	....
milling...........	....
salting...........	....
hooping..........	....
pressing..........	....
dressing..........	....
Total time from setting to pressing	....

Percentage of acid

In milk

when received..................

before adding starter........

after adding starter..........

when rennet added...........

In whey

after curd is cut...............

at dipping.........................

at packing........................

at milling..........................

at salting..........................

Temperature

of milk when received......

when starter added...........

when rennet added...........

when whey removed.........

at pressing.........................

Rennet test

when milk received...........

after adding starter...........

when rennet added...........

Hot iron test

at dipping...........................

at packing..........................

at milling............................

at salting............................

Condition of curd

when cut..

when packed..

when milled..

when salted...

when pressed..

	Color	Rennet	Salt
Amount per 1,000 lbs. of milk	....	....	....
Total amount.....	....	....	....

................per cent fat in whey

............lbs. fat estimated so lost

....................per cent total milk-fat lost in whey

If comments are added on reverse side, put cross here..............

Work and observations by..............................

Assisted by...

YIELD Day and date.. Time..............................

Weight of cheese when removed from press to curing room....................lbs. Serial No...............

...................lbs. milk for 1 lb. cheese

Kind of cheese made ....

...............lbs. cheese per 100 lbs. milk

..........................lbs. cheese for 1 lb. fat in milk

Number of cheeses made ....

...............lbs. cheese for 1 lb. total solids

If comments are added on reverse side put cross here...............

Work and observations by..

Samples for the determination of moisture were taken after the cheeses had been in the curing rooms for three days. In taking these samples three plugs were removed from each cheese, one near the center, one near the outside, and a third between the other two. The three plugs were placed in a bottle with a ground glass stopper. When ready to weigh out the sample, a few minutes later, the stopper was removed and the plugs were chopped fine and mixed with a knife. About five grams

of this mixed sample was placed in a glass dish and weighed accurately to .0001 of a gram. This was done in duplicate. The dishes were then put into a hot-water oven and dried until they had reached a constant weight. They were then reweighed, and the loss of weight was calculated as moisture. If these two samples did not check within one tenth of one per cent, another determination was made. The average loss of the duplicate samples was taken as the amount of water in the cheese.

The cheeses were paraffined as soon as ready — usually when about four days old — boxed, and left at atmospheric temperature. As soon as they were well cured, when about four months old, moisture determinations were again made of the cured cheese. This was done in the same manner as in the case of green cheese. The cheeses had been held at so high a temperature for so long that it was not possible to make moisture determinations of all of them after they were cured, but as many as possible were done.

After the moisture determinations had been made of the cured cheese it was scored by an expert judge.* He knew nothing of the manner in which the cheeses had been made, but merely scored them as he would cheeses for market. He gave each cheese a perfect score.

In the study of the various factors it was suggested that milk at different seasons of the year might possibly affect the results; therefore, half the work was done in early spring and the remainder in summer. In doing the work, one vat was worked normally and the second vat was worked exactly the same except that the factor which was being studied was varied.

The following factors were studied:

1. Effect of coarse- and of fine-cut curd.
2. Effect of high and of low setting temperature.
3. Effect of a high and of a low acid in the whey.
4. Effect of stirring the curd with the hand as the last of the whey is removed, and of not stirring it.
5. Effect of slow and of fast pressure.
6. Effect of piling the curds high and of piling the curds low during the cheddaring process.
7. Effect of large and of small quantities of salt.
8. Effect of temperature at which the curd is held after the whey is removed.
9. Effect of different amounts of rennet.
10. Effect of cutting curd hard and of cutting curd soft.

* G. C. Dutton of South Otselic, New York, State Cheese Instructor.

TABLE 1. EFFECT OF COARSE-CUT CURDS AND OF FINE-CUT CURDS ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Time from setting to hooping: Hours	Time from setting to hooping: Minutes	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Pounds of cured cheese	Percentage of water in cured cheese	Score
83	Coarse	5	5	300	3.9	.24	31.6	37.68	9.49	30.6	36.73	97½
84	Fine			300	3.9	.25	31.5	37.51	9.52	30.6	36.63	96½
85	Coa?se	5	40	300	4.0	.29	32.5	38.57	9.23	30.9	37.89	96½
86	Fine			300	4.0	.32	31.2	37.78	9.61	29.5	37.23	96½
87	Coarse	4	48	300	4.3	.23	33.9	37.92	8.85	32.4	37.57	86
88	Fine			300	4.3	.31	33.1	36.93	9.06	32.2	36.58	97
89	Coarse	6	25	300	4.4	.25	34.8	37.11	8.62	33.2	36.60	96
90	Fine			300	4.4	.26	34.7	37.07	8.65	32.9	36.52	97½
91	Coarse	5	18	300	4.4	.30	34.0	36.57	8.82	32.9	35.93	94½
92	Fine			300	4.4	.31	33.6	35.86	8.93	32.1	35.52	85
93	Coarse	5	14	300	4.4	.35	33.8	35.43	8.87	33.6	34.81	85
94	Fine			300	4.4	.37	33.3	35.38	9.01	33.2	34.35	85
95	Coarse	3	26	296	3.9	.22	31.2	38.71	9.49	30.4	38.40	85
96	Fine			296	3.9	.26	30.9	38.48	9.58	29.8	37.62	91
97	Coarse	4	29	300	4.4	.21	33.8	36.57	8.87	32.4	36.17	85
98	Fine			300	4.4	.26	33.6	36.11	8.93	32.2	35.55	85
194	Coarse	6	12	300	4.1	.29	31.9	34.80	9.40	....	....	89
195	Fine			300	4.1	.33	31.3	34.44	9.58	....	....	91
196	Coarse	5	12	300	4.1	.27	31.5	34.65	9.52	....	....	88
197	P ne			300	4.1	.29	31.2	34.25	9.61	....	....	87
198	Coarse	6	32	300	4.1	.26	32.0	34.99	9.37	....	....	90
199	Fine			300	4.1	.28	31.5	34.48	9.52	....	....	86
Average	Coarse	....	......	299.6	4.18	.26	32.8	36.63	....	32.0	36.76	90.18
Average	Fine	....	......	299.6	4.18	.29	32.3	36.20	....	31.5	36.25	90.68

INFLUENCE OF COARSE-CUT CURDS AND OF FINE-CUT CURDS ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

In the study of this factor the twin vat was used, and both vats were run exactly alike except that one was cut with a one-half-inch, perpendicular, blade knife and the other with a five-sixteenths, perpendicular, wire knife. Both vats were cut with the same one-half-inch, horizontal, blade knife. In each determination the vats were identical except for the cutting; but the amount of acid used, the fat in the milk, and the length of time varied from day to day.

In the study of this factor 3 ounces of rennet extract and 2 pounds of salt were used to 1,000 pounds of milk.

The table on page 519 shows that if curd is cut fine the yield of cheese is reduced, owing to the smaller percentage of moisture and the larger loss of fat in the whey. Of the eleven determinations made, every one shows the same general result. The curd cut coarse was soft and mushy, while the curd cut fine was shotty and firm when the whey was removed. The average score shows, however, that the quality of the cheese was about the same, with a slight difference in favor of the fine-cut. The average of the eleven determinations shows that the curd cut coarse yielded .5 pound more cheese from 299.6 pounds of milk, containing .43 per cent more moisture in the green cheese, and that it lost .03 per cent less fat in the whey.

The following summary, calculated from the figures in Table 1, shows the yield of cheese from coarse- and fine-cut curd:

Pounds of cheese from 1,000 pounds of milk

	Green cheese	Cured cheese
Coarse cut	109.5	106.8
Fine cut	107.0	105.1

Pounds of cheese for 1 pound of fat in milk

	Green cheese	Cured cheese
Coarse cut	2.62	2.55
Fine cut	2.58	2.52

The foregoing tables show that 1,000 pounds of milk yielded 2.5 pounds more green cheese and 1.7 pound more cured cheese when cut with the coarse knife than when cut with the fine knife. This shows that if the curd is cut fine there is a larger loss both of fat in the whey and of moisture than if it is cut coarse.

TABLE 2. EFFECT OF HIGH AND OF LOW SETTING TEMPERATURES ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Setting temperature	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Acidity at setting	Acidity at dipping	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Pounds of cured cheese	Percentage of water in cured cheese	Score
3	High	90	300	4.0	.29	.20	.130	33.56	36.74	9.50	30.28	36.37	96½
1	Low	82	300	4.0	.44	.20	.130	29.80	34.62	10.04	28.96	34.21	94½
4	High	92	300	4.0	.32	.20	.135	32.20	37.09	9.32	31.67	36.85	90½
2	Low	86	300	4.0	.33	.20	.130	30.90	36.43	9.71	30.30	36.00	94½
19	High	93	300	4.2	.23	.20	.125	33.90	37.08	8.85	32.87	36.98	93½
18	Low	84	300	4.2	.30	.20	.120	33.00	36.24	9.09	32.74	35.93	96½
20	High	88	300	4.2	.32	.20	.125	33.21	36.97	9.03	32.84	36.75	96½
17	Low	80	300	4.2	.45	.20	.120	32.00	36.17	9.38	32.16	35.83	96½
7	High	90	300	4.1	.29	.19	.120	31.10	36.46	9.65	30.37	36.16	94
5	Low	80	300	4.1	.39	.19	.120	30.34	36.05	9.89	29.74	35.80	93½
8	High	95	300	4.1	.31	.19	.130	31.88	38.00	9.41	30.94	37.21	91½
6	Low	86	300	4.1	.32	.19	.120	30.72	36.63	9.76	29.16	36.25	93½
127	High	90	337	4.2	.22	.21	.180	37.10	36.94	9.08	35.10	36.44	83
128	Low	80	337	4.2	.30	.21	.170	36.30	36.22	9.28	34.90	36.17	91
139	High	90	225	4.2	.28	.21	.145	25.80	39.62	8.72	24.00	37.16	93
137	Low	78	225	4.2	.37	.21	.140	24.60	36.88	9.14	23.20	35.64	93
209	High	94	300	4.2	.23	.19	.160	34.00	37.63	8.82	....	....	89
208	Low	84	300	4.2	.23	.19	.150	33.10	36.73	9.06	....	....	91
211	High	88	300	4.2	.35	.19	.160	33.00	36.69	9.09	....	....	91
210	Low	80	300	4.2	.41	.19	.155	31.30	36.17	9.58	....	....	93
Average	High	......	296.2	4.14	.284	......	......	32.57	37.32	....	31.00	36.74	91.85
Average	Low	......	296.2	4.14	.354	......	......	31.20	36.21	....	30.14	35.72	93.70

INFLUENCE OF SETTING THE MILK AT HIGH AND AT LOW TEMPERATURES

In this experiment separate vats were used, and the milk was heated to different temperatures at the time of adding the rennet. All other factors were the same. Both vats were cut at the same time, but the vat at the high temperature was much firmer. In this experiment 3 ounces of rennet and 1.5 pound of salt were used to 1,000 pounds of milk.

The table on page 521 shows that the vat set at the high temperature made more cheese. The average of the ten determinations shows that from 296.2 pounds of milk 1.37 pound more green cheese was made, and that the cheese contained 1.11 per cent more moisture, when set at a high temperature. Setting at a high temperature reduced the loss of fat in the whey .07 per cent, probably because the curd became much firmer when cut. The quality of the cheese set at a high temperature was not so good, as the score shows an average of 1.85 point less than the average of the cheese set at a low temperature.

The following summary, calculated from the figures in Table 2, shows the yield of cheese from high and low setting temperatures:

Pounds of cheese from 1,000 pounds of milk

	Green cheese	Cured cheese
High temperature................	109.9	104.6
Low temperature................	105.3	101.7

Pounds of cheese from 1 pound of fat in milk

	Green cheese	Cured cheese
High temperature................	2.65	2.53
Low temperature................	2.54	2.46

The above table shows that from 1,000 pounds of milk 4.6 pounds more green cheese was made when the milk was set at a high temperature than when set at a low temperature. The yield of green cheese was also .11 pound more for each pound of fat in the milk when the milk was set at a high temperature. This increase was probably due to the smaller loss of fat and the increased percentage of moisture.

INFLUENCE OF A HIGH AND OF A LOW ACID IN THE WHEY

In this experiment the twin vat was used. There was the same amount of acid in each vat at the time of setting; both were cooked to the same temperature, but one vat was dipped when the acidity was about .16 per cent and the other was dipped when the acidity was about .20 per

TABLE 3. EFFECT OF DEVELOPING A HIGH AND A LOW ACID IN THE WHEY ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Acidity at setting	Acidity at dipping	Time of setting	Time of dipping	Time of hooping	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Pounds of cured cheese	Percentage of water in cured cheese	Score
117	High	285	4.1	.38	.19	.170	10.11	1.30	4.05	30.3	36.86	9.40	29.4	36.34	90
118	Low	285	4.1	.41	.19	.130	10.11	12.07	4.05	30.9	38.75	9.22	29.8	37.57	90
119	High	300	4.1	.22	.20	.190	11.05	1.30	4.00	31.8	36.08	9.43	30.6	35.06	90
120	Low	300	4.1	.23	.20	.160	11.05	12.25	4.00	32.4	37.20	9.26	31.2	36.96	91
122	High	317	4.2	.22	.21	.210	11.20	2.15	4.00	33.0	38.53	9.60	32.8	35.31	88
121	Low	317	4.2	.20	.21	.155	11.20	1.13	4.00	33.3	39.09	9.52	33.3	37.53	89
123	High	323	4.2	.17	.20	.200	10.45	1.47	3.12	32.8	39.19	9.84	32.0	35.52	89
124	Low	323	4.2	.16	.20	.155	10.45	12.35	3.15	33.6	39.49	9.61	32.8	36.80	83
125	High	337	4.2	.26	.21	.200	11.25	2.20	4.20	36.1	36.64	9.33	34.8	36.16	86
126	Low	337	4.2	.30	.21	.150	11.25	1.00	4.20	36.4	37.03	9.26	35.2	36.97	90
207	High	300	4.2	.20	.19	.190	11.25	3.00	4.35	32.0	36.02	9.37	......	......	89
206	Low	300	4.2	.25	.19	.150	11.25	1.40	4.35	32.7	36.43	9.17	......	......	91
219	High	300	4.3	.22	.18	.185	10.55	2.00	3.40	33.3	35.29	9.01	......	......	91
220	Low	300	4.3	.25	.18	.150	10.55	12.50	3.40	33.6	35.95	8.93	......	......	92
212	High	300	4.2	.19	.18	.190	11.10	2.20	4.00	33.1	37.05	9.06	......	......	88
213	Low	300	4.2	.23	.18	.160	11.10	1.15	4.00	33.5	37.45	8.95	......	......	94
214	High	300	4.2	.20	.18	.190	11.10	2.20	4.00	33.9	37.12	8.85	......	......	87
215	Low	300	4.2	.20	.18	.160	11.10	1.15	4.00	34.5	37.28	8.69	......	......	85
216	High	300	4.2	.20	.18	.190	11.10	2.20	4.00	33.5	37.62	8.95	......	......	89
217	Low	300	4.2	.25	.18	.160	11.10	1.15	4.00	34.6	37.91	8.67	......	......	89
Average	High	306.2	4.19	.226	......	......	......	......	......	32.98	37.04	......	31.9	35.67	88.7
Average	Low	306.2	4.19	.248	......	......	......	......	......	33.55	37.56	......	32.4	37.16	89.4

cent. The curd in the vat with the high content of acid was in the whey about an hour longer than the other curd, and thereby became much firmer.

Both vats were milled at the same time, but the one with the high acid in the whey had slightly more acid when milled. In this experiment 3 ounces of rennet extract and 2 pounds of salt were used for each 1,000 pounds of milk.

The table on page 523 shows that a low acid in the whey increases both the yield and the quality of the cheese. The average of the ten determinations shows that 306.2 pounds of milk yielded .57 pound more green cheese and .5 pound more cured cheese. When the whey was removed while the acid was low, the moisture was increased .62 per cent in the green and 1.5 per cent in the cured cheese. The average score shows that the quality of the cheese was about the same, but the cheese with the high content of acid in the whey scored less because of the acid texture.

The following summary, calculated from the figures in Table 3, shows the yield of cheese when high or low acid is developed in the whey:

Pounds of cheese from 1,000 pounds of milk

	Green cheese	Cured cheese
High acid........................	107.7	104.1
Low acid........................	109.5	105.8

Pounds of cheese for 1 pound of fat in milk

	Green cheese	Cured cheese
High acid........................	2.57	2.48
Low acid........................	2.61	2.52

The above table shows that the yield of cheese from 1,000 pounds of milk is increased by 1.8 pound of green cheese and 1.7 pound of cured cheese by running a low acid in the whey. This is probably due to the increased percentage of moisture in the cheese. The yield of cheese for 1 pound of fat is .04 pound more in the green cheese and .04 pound more in the cured cheese when a low acid is developed in the whey.

INFLUENCE OF STIRRING AND OF NOT STIRRING THE CURD WITH THE HAND AS THE LAST OF THE WHEY IS REMOVED

In this experiment the twin vat was used. Only one factor was varied: at the time of dipping, one vat was stirred with the hand and the other vat was not stirred. In the stirring, the same practice was used that is common with the cheese-maker when curd is not firm enough at the time of drawing the whey. The whey was drawn down to the surface

TABLE 4. EFFECT OF STIRRING AND OF NOT STIRRING THE CURD WITH THE HAND AS THE LAST OF THE WHEY IS REMOVED, ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Time from setting to hooping: Hours	Time from setting to hooping: Minutes	Acidity at setting	Acidity at dipping	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Pounds of cured cheese	Percentage of water in cured cheese	Score
109	Stirred	5	20	.21	.16	272	4.6	.35	31.4	36.17	8.66	30.6	35.40	92
110	Not stirred			.21	.16	272	4.6	.31	31.7	36.75	8.58	30.8	36.02	89
111	Stirred	5	19	.21	.16	300	4.2	.33	31.8	35.12	9.43	30.0	34.69	87
112	Not stirred			.21	.16	300	4.2	.30	32.9	36.85	9.12	31.2	36.22	93
113	Stirred	5	43	.21	.18	300	4.0	.27	32.7	36.05	9.17	32.0	35.38	92
114	Not stirred			.21	.18	300	4.0	.21	33.2	37.49	9.03	32.5	36.79	90
115	Stirred	4	5	.22	.18	300	4.2	.27	32.9	36.19	9.12	32.0	35.70	85
116	Not stirred			.22	.18	300	4.2	.23	34.8	37.67	8.62	33.7	36.43	83
230	Stirred	4	19	.19	.16	300	4.2	.29	31.5	35.14	9.52	....	....	92
229	Not stirred			.19	.16	300	4.2	.21	32.7	36.78	9.17	....	....	91
232	Stirred	4	29	.19	.16	300	4.2	.37	32.4	35.57	9.26	....	....	95½
231	Not stirred			.19	.16	300	4.2	.27	32.7	36.76	9.17	....	....	93
234	Stirred	4	17	.19	.16	300	4.2	.25	33.3	36.40	9.01	....	....	90
233	Not stirred			.19	.16	300	4.2	.23	33.5	36.64	8.95	....	....	92
236	Stirred	4	10	.20	.16	275	4.2	.29	29.9	35.18	9.20	....	....	95½
235	Not stirred			.20	.16	275	4.2	.22	30.1	37.25	9.13	....	....	95½
238	Stirred	3	40	.20	.18	292	4.2	.39	30.4	34.67	9.60	....	....	96
237	Not stirred			.20	.18	292	4.2	.24	31.9	36.65	9.15	....	....	94
Average	Stirred	....	......	......	......	293.2	4.22	.312	31.8	35.61	....	31.1	35.29	91.6
Average	Not stirred	....	......	......	......	293.2	4.22	.246	32.6	36.98	....	32.0	36.36	91.1

of the curd and the curd was stirred over several times, and then the gate was opened and the whey allowed to run. The stirring was continued until all the whey was removed; this took about three minutes, on the average. Then the curd was piled the same in both vats and these were handled in the same manner throughout the remainder of the process. Both vats had the same amount of acid at the time of setting and dipping, but the vat that was not stirred developed a trifle more acid at the time of milling.

In this experiment 3 ounces of rennet extract and 2 pounds of salt were used to 1,000 pounds of milk.

The average of the preceding table shows that from 293.2 pounds of milk, testing 4.22 per cent fat, the vat not stirred as the whey was removed yielded 32.6 pounds of green cheese containing 36.98 per cent of moisture, and 32 pounds of cured cheese containing 36.36 per cent of moisture. This is an increase in yield over the vat that was stirred when the whey was removed, of .8 pound of green cheese containing 1.37 per cent more moisture and .9 pound of cured cheese containing 1.07 per cent more moisture. Had the curd been stirred longer there would undoubtedly have been a greater difference. The average loss of fat increased .066 per cent when the curd was stirred in the whey. The column of scores shows that there is a slight difference in quality in favor of the stirring.

The following summary, calculated from the figures in Table 4, shows the yield of cheese when stirred with the hand as the last of the whey is removed, and when not stirred:

Pounds of cheese from 1,000 pounds of milk

	Green cheese	Cured cheese
Stirred	108.5	106.1
Not stirred	111.2	109.1

Pounds of milk for 1 pound of fat in cheese

	Green cheese	Cured cheese
Stirred	2.57	2.51
Not stirred	2.72	2.58

This table shows that from 1,000 pounds of milk not stirred, the yield of green cheese is increased 2.7 pounds and of cured cheese 3 pounds. This increase is due to the smaller loss of fat in the whey and the higher percentage of moisture in the cheese. The increased yield for each pound of fat, as a result of the curd not being stirred as the whey is removed, is .15 pound in the green cheese and .07 pound in the cured cheese. Hand-

stirring increases the loss of fat in the whey and reduces the amount of moisture in the cheese. The scores show that this improves the quality of the cheese slightly. This is especially true of milk with a high acid, for the curd does not have time to firm up naturally before the whey is removed.

INFLUENCE OF APPLYING FULL PRESSURE AT ONCE OR GRADUALLY

In this series of experiments, the cheese curds were all made in a large vat under the same conditions. At the time of hooping, the same amount of curd was weighed into each hoop. Then half of the hoops were placed in a steel gang press and full pressure was applied at once; the other half were put into the same kind of a press, but pressure was applied gradually until full pressure was reached.

TABLE 5. EFFECT OF FAST AND OF SLOW PRESSURE ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Pounds of curd	Pounds of green cheese	Percentage of water in green cheese	Score
166	Fast	33	30.60	36.46	86
167	Fast	33	29.20	36.30	87
168	Fast	33	30.16	37.15	90
169	Slow	33	31.12	36.75	85
170	Slow	33	31.36	37.02	85
173	Fast	38	36.20	38.72	87
174	Fast	38	36.20	38.70	80
175	Slow	38	36.20	38.54	81
177	Fast	76	74.20	38.70	90
178	Slow	76	74.50	38.92	87
179	Fast	73	71.10	36.91	88
180	Slow	73	71.60	37.95	81
200	Fast	40	38.20	35.91	91
200	Fast	40	38.20	35.88	91
200	Fast	40	38.76	36.17	87
201	Slow	40	38.00	35.91	91
201	Slow	40	37.80	35.74	91
201	Slow	40	37.70	35.69	91
14	Fast	37	35.20	35.88	92½
14	Fast	37	34.96	36.27	95½
14	Fast	37	34.80	36.50	96½
15	Slow	37	35.00	36.75	96½
15	Slow	37	34.56	36.41	......
413	Fast	38	34.40	35.57	96½
414	Slow	38	34.52	36.10	96½

TABLE 5 (*continued*)

Serial number	Method	Pounds of curd	Pounds of green cheese	Percentage of water in green cheese	Score
418	Fast	37	34.30	35.54	94½
419	Slow	37	34.62	35.54	94½
11	Fast	40	35.42	36.69	97½
11	Fast	40	35.52	37.56	97½
12	Slow	40	35.29	36.17	97½
12	Slow	40	35.52	36.48	96½
9	Fast	37	35.82	35.29	94¼
9	Fast	37	36.00	35.33	93½
10	Slow	37	36.07	35.22	96½
10	Slow	37	36.10	35.64	95½

Weight of curd pressed fast	784 pounds
Weight of curd pressed slow	676 pounds
Weight of green cheese pressed fast	739.24 pounds
Weight of green cheese pressed slow	639.96 pounds
Curd lost, pressed fast	5.70 per cent
Curd lost, pressed slow	5.33 per cent
Average moisture in cheese pressed fast	36.60 per cent
Average moisture in cheese pressed slow	36.55 per cent

The average of the table shows that the curd pressed fast lost .37 per cent more weight than the curd to which pressure was gradually applied. The results of the separate determinations do not all show the same results. Some cheeses weigh more when pressed fast and others when pressed slow. The percentage of moisture seems to vary in the different determinations, being first in favor of slow pressure and then in favor of fast pressure. The average moisture seems to be .05 per cent more in the curd pressed fast. The fact that the cheese pressed fast lost more in weight and had a higher percentage of moisture may be due to a larger loss of fat in the press when the curds were pressed fast.

INFLUENCE OF PILING CURDS HIGH AND OF PILING CURDS LOW DURING THE CHEDDARING PROCESS

In this series of experiments the twin vat was used, and the only factor that was varied was the depth of piling the curds. One vat was piled about four to five inches deep and the other about ten to twelve inches deep. After the curds had been in the "pack" for about an hour those curds piled deeper were doubled, so that their depth was about twenty inches.

TABLE 6. 'EFFECT OF PILING CURDS HIGH AND OF PILING CURDS LOW DURING THE CHEDDARING PROCESS ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Acidity at dipping	Acidity at milling (inches)	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Pounds of cured cheese	Percentage of water in cured cheese	Score
99	High	300	4.1	.30	.17	[illegible]	31.5	36.05	9.52	30.8	35.27	87
100	Low	300	4.1	.29	.17	[illegible]	31.1	35.78	9.64	30.5	35.14	90
101	High	300	3.7	.24	.16	[illegible]	31.2	37.55	9.61	30.2	36.54	91
102	Low	300	3.7	.25	.16	[illegible]	30.8	36.84	9.74	30.0	36.50	88
103	High	300	4.2	.41	.19	[illegible]	32.8	37.65	9.14	31.8	36.75	83
104	Low	300	4.2	.46	.19	[illegible]	32.2	35.73	9.31	31.2	35.14	86
105	High	300	4.2	.26	.18	[illegible]	32.8	37.54	9.14	30.6	36.32	86
106	Low	300	4.2	.30	.18	[illegible]	32.2	35.64	9.31	30.2	35.31	86
107	High	282	4.6	.20	.18	[illegible]	34.3	37.41	8.22	32.9	37.04	87
108	Low	282	4.6	.22	.18	[illegible]	34.0	37.25	8.29	32.5	36.89	86
241	High	330	4.2	.20	.17	[illegible]	37.0	39.37	8.96	....	....	90
242	Low	330	4.2	.21	.17	[illegible]	36.8	37.01	8.91	....	....	87
239	High	300	4.2	.19	.17	[illegible]	34.7	38.79	8.64	....	....	83
240	Low	300	4.2	.20	.17	[illegible]	33.5	37.68	8.95	....	....	85
Average	High	301.7	4.1	.257	....	......	33.4	37.76	....	31.2	36.38	86.7
Average	Low	301.7	4.1	.275	....	......	32.9	36.56	....	30.8	35.79	86.8

The average of the table shows that 301.7 pounds of milk, testing 4.1 per cent fat, yielded, when the curd was piled high, 33.4 pounds of green cheese containing 37.76 per cent moisture, and 31.2 pounds of cured cheese containing 36.38 per cent of moisture. This is a gain over piling the curd low of .5 pound of green cheese and .4 pound of cured cheese from 301.7 pounds of milk. The cheese piled high contained 1.2 per cent more moisture in the green cheese and .59 per cent more moisture in the cured cheese, than did the cheese piled low. The average score would indicate that the quality of the cheese was the same.

The following summary, calculated from the figures in Table 6, shows the yield of cheese from curds piled high and from curds piled low in the cheddaring process:

Pounds of cheese from 1,000 pounds of milk

	Green cheese	Cured cheese
Piled high	110.8	103.4
Piled low	109.0	102.1

Pounds of cheese for 1 pound of fat in milk

	Green cheese	Cured cheese
Piled high	2.70	2.52
Piled low	2.66	2.50

This table shows that by piling the curd high the yield of cheese from 1,000 pounds of milk is increased by 1.8 pound of green cheese and 1.3 pound of cured cheese. While the average score would indicate that the quality of the cheese was the same, the cheeses piled high seemed to be a trifle pasty in texture.

INFLUENCE OF THE AMOUNT OF SALT USED

In this series of experiments the cheeses were all made in a large vat. After the curd had been milled, it was weighed into equal amounts and salted at various rates per 1,000 pounds of milk.

TABLE 7. EFFECT OF VARYING AMOUNTS OF SALT ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Pounds of salt used	Weight of curd	Pounds of green cheese	Percentage of water in green cheese	Score
181	1	33	30.9	37.61	81
182	1½	33	30.7	36.28	93
183	2	33	30.6	36.17	91
184	3	33	30.5	35.00	93
185	5	33	30.3	33.25	93

TABLE 7 (*continued*)

Serial number	Pounds of salt used	Weight of curd	Pounds of green cheese	Percentage of water in green cheese	Score
186	1	35	33.6	38.15	81
187	1½	35	33.4	37.06	87
188	3	35	33.1	34.92	91
189	5	35	32.2	32.87	90
190	1	36	33.8	38.37	87
191	1½	36	33.7	37.97	81
192	3	36	32.4	36.78	87
193	5	36	31.2	34.33	91
251	1½	35	32.3	37.92	83
252	2	35	32.2	37.59	85
253	3	35	31.7	36.31	88
254	4	35	31.2	34.15	87
255	5	35	30.5	34.06	87
271	2	40	37.7	36.07	91
272	3	40	36.8	35.01	90
273	5	40	35.9	33.39	90
262	2	39	36.1	36.83	91
263	3	39	35.0	35.29	90
264	5	39	34.8	33.25	92

The table shows that as the amount of salt is increased, both the yield of cheese and the percentage of moisture in the cheese is decreased. The scores would indicate that as the salt is increased, to a certain point, the quality is increased. If too small an amount of salt is used, the cheese will be bitter. If too much salt is used, the cheese has a salty taste and the curing is delayed.

INFLUENCE OF THE TEMPERATURE AT WHICH THE CURD IS HELD AFTER THE WHEY IS REMOVED

In this series of experiments the twin vat was used. Conditions were the same until the whey had been removed; then the curd in one vat was allowed to cool and in the other it was kept at a temperature of 100° F. In order to keep the temperature at 100° F., the vat was covered and a pail of hot water that was changed from time to time was placed in the vat. In this experiment 3 ounces of rennet extract and 2.5 pounds of salt were used to 1,000 pounds of milk.

This table shows that if the curd is held at a high temperature the yield is reduced and likewise the moisture and the quality of the cheese.

TABLE 8. EFFECT OF THE TEMPERATURE AT WHICH THE CURD IS HELD AFTER THE WHEY IS REMOVED, ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Temperature when whey was removed	Temperature of curd at milling	Acidity at dipping	Acidity at milling (inches)	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Pounds of cured cheese	Percentage of water in cured cheese	Score
129	High	300	4.1	.25	98	100	.19	[illegible]	31.5	36.68	9.52	29.8	35.65	81
130	Cooled	300	4.1	.24	98	98	.19	[illegible]	32.3	37.68	9.28	30.1	36.25	85
132	High	206	4.0	.21	100	100	.18	[illegible]	22.8	36.72	9.03	21.7	36.48	85
133	Cooled	206	4.0	.22	100	96	.18	[illegible]	23.4	40.18	8.80	21.8	36.88	85
134	High	300	4.2	.30	100	102	.16	[illegible]	30.6	36.70	9.80	29.5	35.42	85
135	Cooled	300	4.2	.29	100	93	.16	[illegible]	31.2	37.41	9.61	30.0	36.92	87
246	High	300	4.3	.29	98	100	.18	[illegible]	31.8	35.25	9.14	....	....	94
245	Cooled	300	4.3	.28	98	96	.18	[illegible]	32.0	36.32	9.67	....	....	96
249	High	350	4.3	.25	98	100	.18	[illegible]	37.4	36.05	9.35	....	....	85
248	Cooled	350	4.3	.28	98	94	.18	[illegible]	38.0	36.43	9.21	....	....	89
463	High	300	4.3	.29	98	100	.18	[illegible]	30.5	35.25	9.52	....	....	84
464	Cooled	300	4.3	.29	98	96	.18	[illegible]	30.9	36.28	9.70	....	....	86
465	High	300	4.3	.24	98	100	.18	[illegible]	32.4	36.15	9.25	....	....	91
467	Cooled	300	4.3	.23	98	96	.18	[illegible]	32.9	37.25	9.11	....	....	90
Average	High	293.7	4.2	.261	......	......	......	......	31.0	36.11	....	27.0	35.85	86.4
Average	Cooled	293.7	4.2	.261	......	......	......	......	31.5	37.36	....	27.3	36.68	88.2

The curd held at the high temperature was soft and mushy at the time of milling and lost a considerable amount of white whey. After salt was applied, the white whey ran freely from the curd. The curd at low temperature was firm and lost little, if any, white whey.

The following summary, calculated from the figures in Table 8, shows the yield of cheese held at high and at low temperature during the cheddaring process:

Pounds of cheese from 1,000 pounds of milk

	Green cheese	Cured cheese
High temperature	105.5	91.9
Low temperature	107.3	93.0

Pounds of cheese for 1 pound of fat in the milk

	Green cheese	Cured cheese
High temperature	2.51	2.19
Low temperature	2.55	2.21

This table shows that if curd is held at a low temperature, the yield of cheese from 1,000 pounds of milk is increased by 1.8 pound of green cheese and 1.1 pound of cured cheese. This increase is made at a gain in the quality of the cheese, as shown by the scores.

INFLUENCE OF THE USE OF VARYING AMOUNTS OF RENNET EXTRACT

In this experiment the milk was run into the large vat, thoroughly mixed and ripened, and then put into the small vats. Rennet was added at the various rates per 1,000 pounds of milk, as the table shows. The rate in the table is given in ounces, as this is the usual measure used in cheese factories. The amount of rennet extract necessary for each vat was computed in cubic centimeters, and a cylinder graduated into cubic centimeters was used for measuring it since this was much more accurate than to measure so small a quantity in ounces. The rennet was added to all the vats at the same time, and they were all cut at the time when the vat with the least amount of rennet was ready to be cut. Those having the greater amounts of rennet were much harder at the time of cutting. Throughout the remainder of the experiment the curds were handled in the same manner. The same amount of salt was used on each vat. The grouping indicates those vats that were made from the same milk and were otherwise alike except for the amount of rennet extract used.

TABLE 9. EFFECT OF VARYING AMOUNTS OF RENNET ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Ounces of rennet used for 1,000 pounds of milk	Pounds of milk	Percentage of fat in milk	Percentage of fat lost in whey	Pounds of green cheese	Percentage of water in green cheese	Score
25	3	300	4.3	.32	29.1	35.49	92½
21	5	300	4.3	.23	33.9	36.88	94½
22	8	300	4.3	.20	34.1	37.35	95½
23	16	300	4.3	.23	35.1	37.75	92½
24	20	300	4.3	.23	34.5	37.57	92½
160	3	300	4.2	.16	31.4	36.87	91
163	8	300	4.2	.15	31.4	37.81	87
161	12	300	4.2	.09	31.9	37.56	87
162	16	300	4.2	.07	31.7	37.38	85
164	3	300	3.6	.26	31.0	38.83	90
165	20	300	3.6	.25	31.4	39.58	75
171	3	300	4.2	.25	32.6	38.75	78
172	8	300	4.2	.25	33.2	39.71	85
256	3	300	4.4	.32	33.3	35.68	89
257	5	300	4.4	.30	32.8	36.32	93
258	8	300	4.4	.33	33.4	36.37	89
259	12	300	4.4	.31	33.4	36.40	91
260	16	300	4.4	.34	34.0	34.47	88
261	20	300	4.4	.35	34.2	38.62	85
265	3	300	4.2	.25	32.6	35.03	92
266	5	300	4.2	.29	32.7	36.50	94
267	8	300	4.2	.22	33.2	36.69	93
269	16	300	4.2	.25	33.7	37.87	83
270	20	300	4.2	.27	33.4	36.98	83

The table shows that, up to a certain point, as the amount of rennet extract is increased the yield of cheese is increased and the percentage of moisture in the cheese is increased. The maximum yield seems to be reached when 16 ounces of rennet extract are used, and then begins to fall. However, this increased yield is gained at a sacrifice in the quality of the cheese, as is shown by the score. The use of such large amounts of rennet extract would not be practical as it would be too expensive.

INFLUENCE OF CUTTING CURD HARD AND OF CUTTING CURD SOFT

In this series of experiments the twin vat was used, and each compartment was heated to the same temperature. In one the curd was cut while soft and in the other while hard. The first was cut so soft that the knife would scarcely leave a mark, and the second was so hard that the curd

broke in some cases ahead of the knife. After the curds were cut they were handled alike throughout the remainder of the process.

TABLE 10. EFFECT OF CUTTING THE CURD HARD AND OF CUTTING THE CURD SOFT, ON THE YIELD AND THE MOISTURE CONTENT OF THE CHEESE

Serial number	Method	Minutes from adding rennet to cutting	Pounds of milk	Per-centage of fat	Per-centage of fat lost in whey	Pounds of green cheese	Percentage of water in green cheese	Pounds of milk for 1 pound of green cheese	Score
26.........	Hard....	35	300	4.0	.27	32.62	37.31	9.19	95½
27.........	Soft....	20	300	4.0	.35	31.80	36.06	9.43	95½
34.........	Hard....	35	300	4.4	.30	34.60	35.87	8.67	95½
32.........	Soft....	20	300	4.4	.40	33.06	35.07	9.07	93½
33.........	Hard....	35	300	4.4	.30	34.10	36.31	8.80	96½
31.........	Soft....	20	300	4.4	.38	33.06	35.54	9.07	94½
329.........	Hard....	50	300	4.0	.09	32.58	36.21	9.21	95½
328.........	Soft....	15	300	4.0	.45	31.06	34.65	9.65	94
331.........	Hard....	25	300	4.4	.27	33.87	35.28	8.86	96
332.........	Soft....	14	300	4.4	.31	32.08	34.19	9.35	95
Average.....	Hard....	....	300	4.24	.246	33.55	36.19	....	95.7
Average.....	Soft....	....	300	4.24	.378	32.21	35.10	....	94.5

This table shows that if the curd is cut soft the yield of cheese and the percentage of moisture are decreased. The average shows .13 per cent greater loss of fat in the whey when the curd is cut soft than when it is cut hard. The average score shows that the quality of the cheese cut when the curd was hard is better. This is because the cheeses cut soft became too firm and were therefore of poorer texture.

The following summary, calculated from the figures in Table 10, shows the yield of cheese from curds cut hard and soft:

Yield of cheese from 1,000 pounds of milk

	Green cheese
Cut hard....................................	111.8
Cut soft....................................	107.3

Pounds of cheese from 1 pound of fat in milk

	Green cheese
Cut hard....................................	2.63
Cut soft....................................	2.53

This table shows that the yield of cheese from 1,000 pounds of milk is 4.5 pounds greater when the curd is cut hard. This is due to the fact that the percentage of moisture is 1.09 per cent greater. Cutting the curd soft is one of the best ways of decreasing the moisture, but the loss of fat in the whey is greater.

CONCLUSIONS

1. Cutting the curd fine causes a larger loss of fat in the whey than cutting the curd coarse. Coarse-cut curd increases the yield of green and of cured cheese and increases the moisture content of the cheese. If great care is not taken and the pieces of curd are broken, the result will be the same as a fine cut.

2. Setting the milk at a high temperature reduces the loss of fat in the whey more than setting the milk at a low temperature. Setting at a high temperature increases the yield of the green and the cured cheese. This increase is probably due to the increased moisture content of the cheese.

3. A low acid at the time of removing the whey increases the yield of the green and the cured cheese. The low acid also increases the percentage of moisture in the cheese. If a high acid is developed, it not only reduces the yield and the percentage of moisture in the cheese, but also injures the quality of the cheese.

4. Stirring the curd with the hand as the last of the whey is removed reduces the percentage of moisture in the green and the cured cheese. Stirring reduces the yield and causes a larger loss of fat in the whey.

5. Pressing the curd fast reduces the yield because more fat is squeezed out of the curd. This loss of fat makes the cheese pressed fast appear to contain more moisture.

6. If the curds are piled deep more moisture is retained in the green and the cured cheese. Piling the curds deep increases the yield of cheese.

7. An increase of salt in the curd results in the reduction of moisture in the cheese.

8. Holding the curd at a low temperature after the whey is removed increases the percentage of moisture in the green and the cured cheese and increases the yield.

9. An increase of rennet to a certain point increases the moisture content of cheese. This is due to greater coagulation, and has the same effect as setting at a high temperature or cutting the curd hard.

10. Cutting the curd soft reduces the percentage of moisture and the yield of the green cheese, and also increases the loss of fat in the whey. Cutting soft has the same effect as setting at a low temperature or as a small amount of rennet.

Factors that reduce the yield and the moisture content of the cheese

1. *Fine cutting.*
2. *Low setting temperature.*
3. *High acid in the curd at time of removing the whey.*
4. *Stirring the curd with the hand as the last of the whey is removed.*

5. *Fast pressure.*
6. *Low piling of the curd in the cheddaring process.*
7. *Large amount of salt.*
8. *Holding the curd at high temperature after the whey is removed.*
9. *Small amount of rennet.*
10. *Cutting the curd soft.*

Factors that increase the yield and the moisture content of the cheese

1. *Coarse cutting.*
2. *High setting temperature.*
3. *Low acid in the curd at time of removing the whey.*
4. *Not stirring the curd with the hand as the last of the whey is removed.*
5. *Slow pressure.*
6. *High piling of the curd in the cheddaring process.*
7. *Small amount of salt.*
8. *Holding the curd at low temperature after the whey is removed.*
9. *Large amount of rennet.*
10. *Cutting the curd hard.*

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THE COLLEGE OF AGRICULTURE

Department of Plant Pathology

SCAB DISEASE OF APPLES

By ERRETT WALLACE

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SCAB DISEASE OF APPLES*

ERRETT WALLACE

(*Received for publication June 1, 1913*)

THE HOST

Consideration of the origin, evolution, distribution, and methods of care and cultivation of the plants affected by a specific disease is often of assistance in reaching conclusions as to the origin and history of the disease, its possible distribution, and its economic importance. In the case of the apple these facts are rather generally known or are readily obtained from various horticultural books. To residents of New York State this information is especially accessible in the excellent work by Beach (1905) entitled "The Apples of New York." It is therefore not necessary, in this bulletin, to enter into an extended discussion of these features further than to indicate in a general way the distribution and importance of the apple industry.

THE APPLE IN THE UNITED STATES

Throughout the United States the apple is more generally cultivated than is any other fruit. The range of latitude in which it can be grown and the diversity of soil suitable for apple culture makes possible this wide distribution; while the universal demand for the fruit as a staple article of diet offers a special inducement for its production.

The census report for 1910 shows that apples are being grown in every state and territory in the Union except Alaska. In some of these localities, however, such small quantities are produced that the industry cannot be considered to be of commercial importance. Among these may be mentioned Florida, Louisiana, Wyoming, Arizona, Nevada, and North Dakota, in each of which States less than 100,000 bushels of apples were produced in 1909.

The accompanying table, compiled from the Thirteenth Census Report, shows the production of the leading apple-growing States in 1909 and in 1899, together with the total production in the United States for those years:

* Also presented to the Faculty of the Graduate School of Cornell University, June, 1911, as a major thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

(1905) Beach, S. A. The apples of New York. Vol. I. New York (Geneva) Agr. Exp. Sta. Rept. 1903:2:1–409.

TABLE I. PRODUCTION OF APPLES IN 1909 AND IN 1899

	1909		1899
	Production (bushels)	Value	Production (bushels)
United States	147,522,318	$83,231,492	175,397,600
New York	25,409,324	13,343,028	24,111,257
Michigan	12,332,296	5,969,080	8,931,569
Pennsylvania	11,048,430	5,557,616	24,060,651
Missouri	9,968,977	4,885,544	6,496,436
Kentucky	7,368,499	3,066,776	6,053,717
Iowa	6,746,668	3,550,729	3,129,862
California	6,335,073	2,901,662	3,488,208
Virginia	6,103,941	3,129,832	9,835,982
North Carolina	4,775,693	2,014,670	4,662,751
Ohio	4,663,752	2,970,851	20,617,480
Tennessee	4,640,444	2,172,475	5,387,775
West Virginia	4,225,163	2,461,074	7,495,743
Maine	3,636,181	2,121,816	1,421,773

THE APPLE IN NEW YORK

In New York State the apple has assumed an important place in recent years. It is the basis on which rests an industry that has made independent thousands of farmers throughout the State and has given to many communities a general air of prosperity and thrift, for which the rural sections of this State, as a rule, are noted. In western New York, particularly, the soil and the climate are so well adapted to apple-growing that the industry has assumed notably large proportions. In this State the two great commercial varieties, Baldwin and Rhode Island Greening, flourish; however, although taking the lead, these are by no means the only varieties of importance.

The Thirteenth Census shows that New York produced in 1909 more than twenty-five million bushels of apples, worth over thirteen million dollars. This production is more than twice that of any other State. The production of all orchard fruits in the State amounted to 29,456,291 bushels, with a value of $17,988,894. It is therefore evident that the apple is of much greater commercial importance in New York State than are all other orchard fruits combined.

THE DISEASE

NAMES APPLIED

The disease, which is known as scab, black spot, scurf, or the fungus, and which has in some cases been called rust, occurs on the leaves and the

fruit, and occasionally has been found on the twigs, of the apple. The name "scab" is used almost exclusively in the United States and is the name that will be used in this account.

HISTORY

The scab disease apparently exists in every country where apples are grown. It was reported early in the nineteenth century by Fries (1819) from Sweden, and some years later by Wallroth (1833) from Germany. The first authentic record from America is by Schweinitz (1834), who reports scab on Newton Pippins in New York and Pennsylvania. The disease was first noticed in England in 1845, according to Berkeley (1855), and in Australia in 1862, according to McAlpine (1902). Its introduction into Australia was attributed to a Seckel pear imported from America; this is doubtful, however, since the scab disease of the pear has since been shown to be entirely distinct from that of the apple.

SYMPTOMS

On the leaves

The scab is likely to appear earliest on the lower side of the leaves. The diseased area usually appears first as an olive discoloration slightly darker than the normal surface of the leaf. The color deepens with age until dark brown or black is reached, the spot having a more or less velvet-like appearance. As noted by Aderhold (1896), on the lower side of the leaf there is a tendency for the lesion to extend along the veins and the midrib and to diffuse irregularly and indefinitely into the healthy area; whereas on the upper surface of the leaf the lesion appears first as a slight olive-green discoloration, of a lighter shade of green than the healthy surface of the leaf but dull and somewhat velvety. The natural luster characteristic of the upper surface of the leaf is destroyed. The spots may be few and scattered; or they may be so numerous as to coalesce, coating almost the entire surface. The diseased areas may be distinctly bordered or they may spread out irregularly and indefinitely into the healthy part of the leaf. In Plate I, Plate II, Fig. 1, and Plate III, Fig. 2, are shown various types of infestation, on both the upper and the lower surfaces of the leaves.

Later the scab spots become darker, changing to brown and finally, in some cases, to nearly black. In some cases the natural form of the leaf

(1819) Fries, Elias. Spilocæa Pomi Fr. Nov. fl. Suec. 5:79.
(1833) Wallroth, F. G. Cladosporium dendriticum W. Fl. crypt. Germ. 2:4:169.
(1834) Schweinitz, L. D. de. Spilocæa fructigena aut Pomi Lk. Syn. F. N. A., p. 297.
(1855) Berkeley, M. J. Why do pears and apples crack? Gard. chron. 1855:724.
(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25:881.
(1902) McAlpine, D. The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. 1:703-708.

is not destroyed; in other cases some distortion results. Very often the diseased surface protrudes, forming a convex surface with a corresponding concavity on the opposite side of the leaf. In time the tissue under many of the diseased spots is killed outright, forming dead areas, which often crack as shrinkage occurs. This condition is most common near the close of the season. In extreme cases considerable defoliation may result (Plate II, Fig. 2).

On the fruit

The lesion on the fruit usually appears from the first as a darker-colored spot than is produced by the disease on the leaves. Sometimes the spots are almost black when first visible; or they may be dark olive, changing to reddish brown or black. The spots are usually very small at first and they enlarge more slowly than do those on the leaves. They are more sharply bordered on the fruit than on the leaves (Plates IV and V).

As the scab spot on the fruit grows older its appearance changes markedly. The central and older part becomes bare, brown, and corky, while the margin is black. A more or less whitish band, due to the loosened cuticle, may surround the black margin (Plate VI, Fig. 2). Sometimes the scab spots may enlarge so as to cover rather large areas and cracking of the fruit results, due to excessive loss of moisture content from the underlying unprotected tissues (Plate III, Fig. 1).

Scab spots resulting from late autumn infection differ somewhat in appearance from those developing early while the fruit is very young. The spots as they first appear are more dense and black. Often they will have enlarged considerably before the cuticle is ruptured. They seldom reach the stage described above, in which the center becomes bare and brown (Plate VI, Fig. 1).

On the twigs

The disease rarely occurs on the twigs, at least in many localities. Affected twigs have, in general, a scurfy appearance. The bark becomes blistered and later ruptured in places, presenting an appearance similar to scabby pear twigs, which are very common. The occurrence of twig infection is discussed at greater length elsewhere in this bulletin.

IMPORTANCE

General estimates of loss

McAlpine (1902) estimated the annual average loss due to apple scab in Victoria, Australia, at £40,000 (approximately $194,000), which is

(1902) McAlpine, D. The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. 1:705.

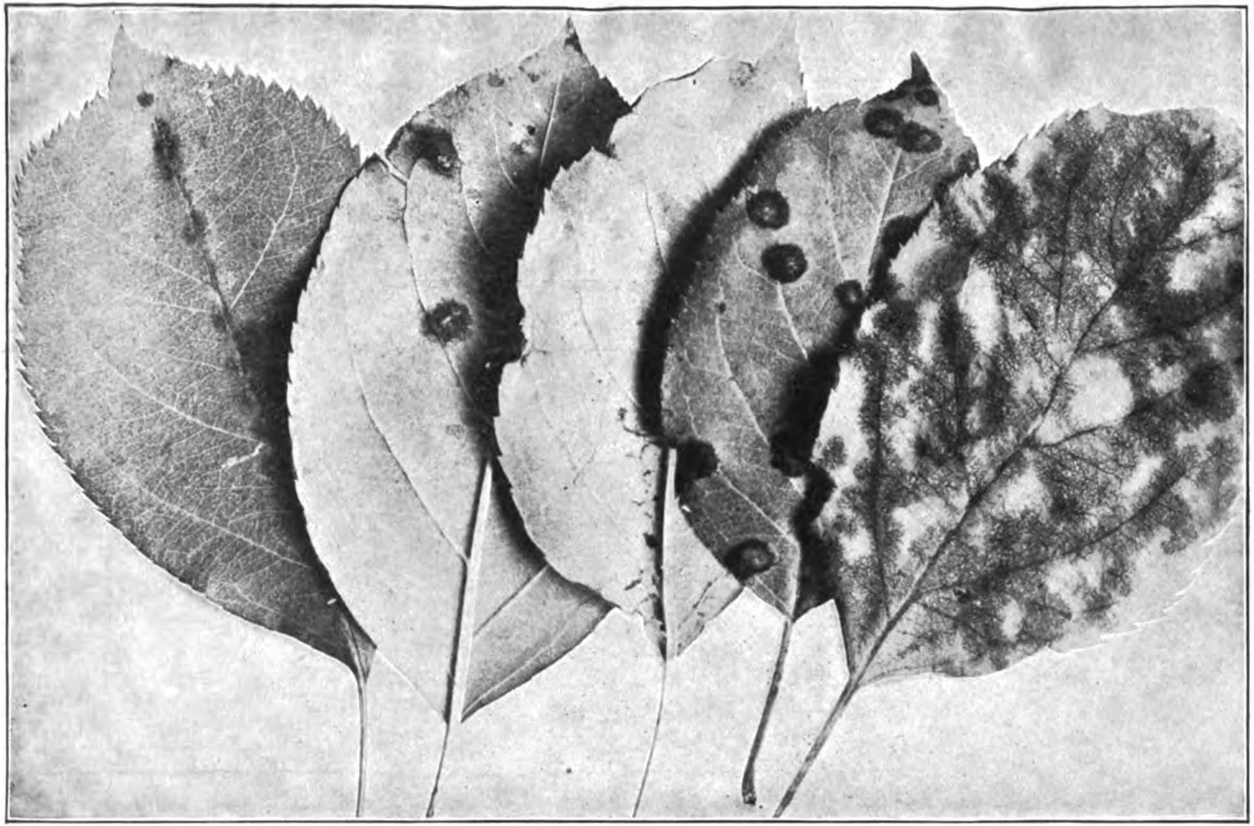
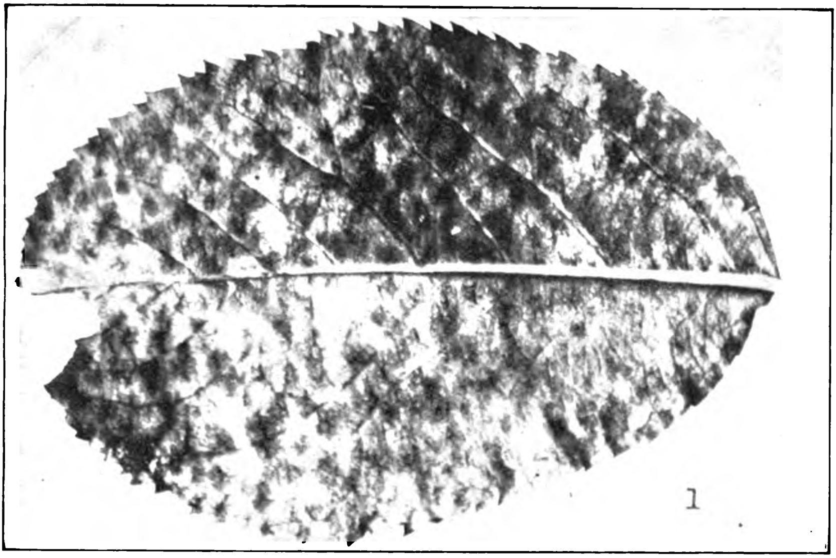


PLATE I.— *Apple-scab disease on leaves. Showing various types of lesions on both upper and lower sides. Photograph made in 1908. Somewhat reduced*



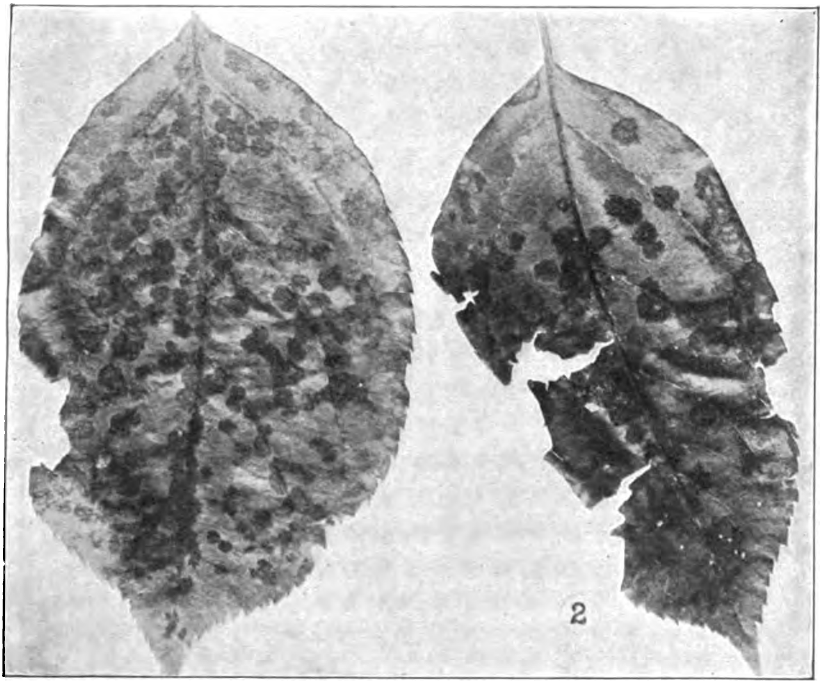
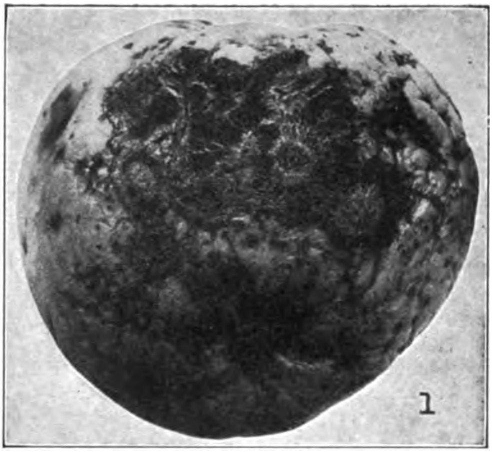


PLATE II. FIG. 1.— *A severe infestation of scab artificially produced by inoculation of protected foliage with ascospores of Venturia inæqualis. Photograph made twenty days after inoculation. Natural size*

FIG. 2.— *Badly infested leaves as they appear late in the season. Photograph made on August 15, 1908. Natural size*



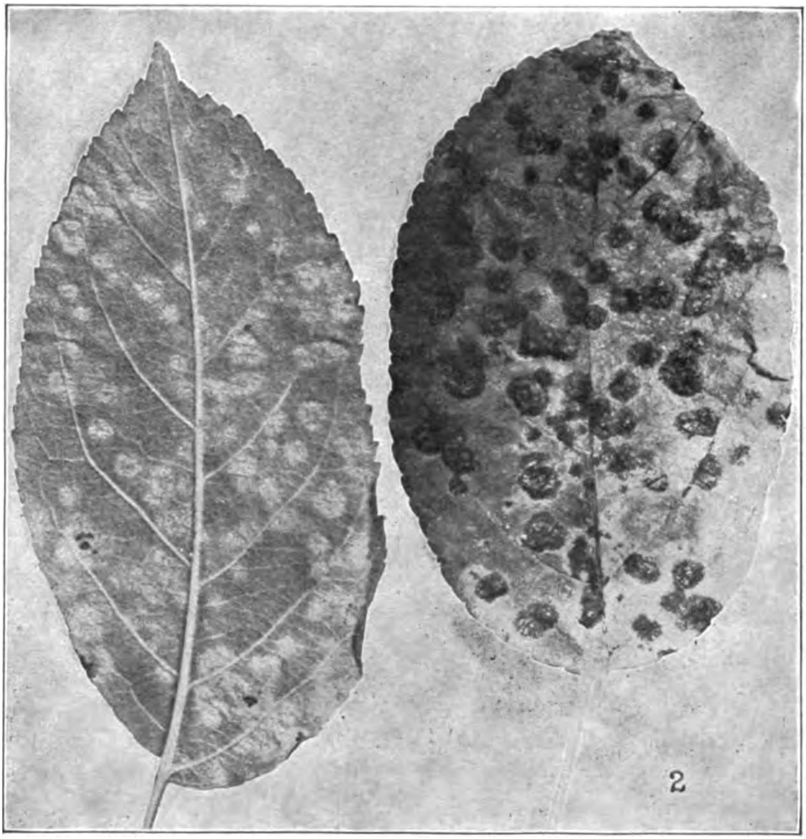


PLATE III. FIG. 1.— *Severe infestation of scab. The fruit is cracked in places, while the old spots appear corky. Many of the spots are small, the result of late infection. Photograph made on October 14, 1908. Natural size*

FIG. 2.— *Scab lesions on upper surface of leaf only, producing a cup-like effect beneath. A common occurrence in cases of severe infestation. Photograph made by Fisher, August 7, 1912. Natural size*

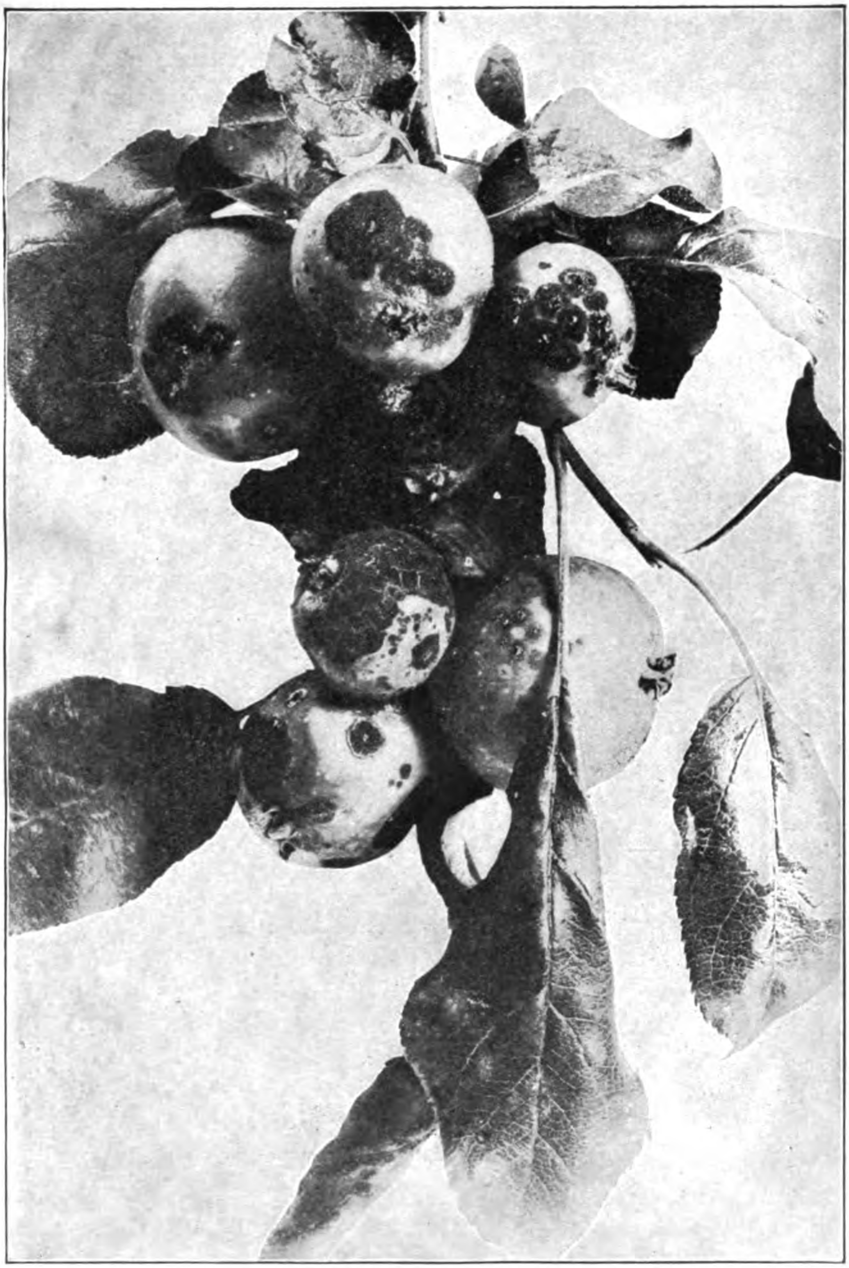
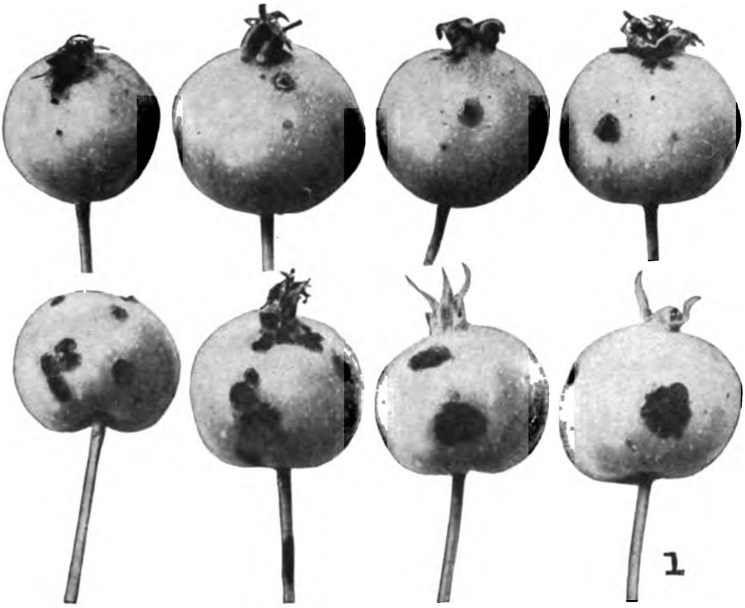


PLATE IV.— *Cluster of badly scabbed apples showing typical lesions. Photograph made by Whetzel, July 31, 1906. Natural size*



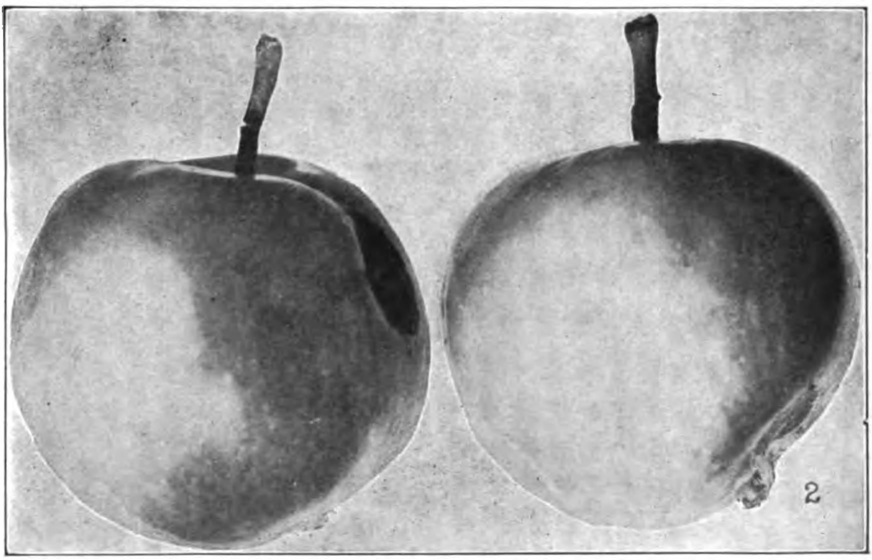
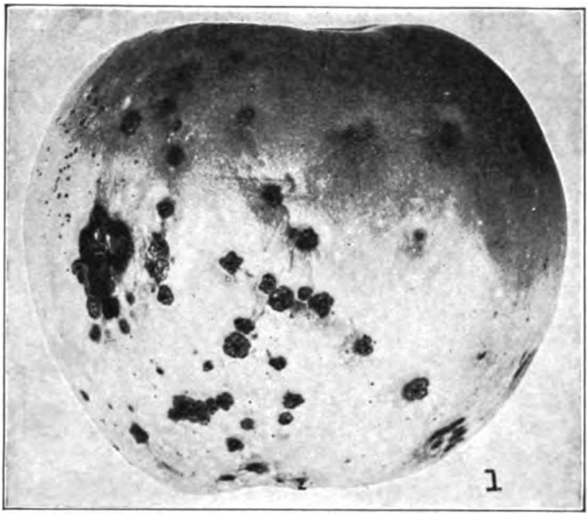


PLATE V. FIG. 1.— *Successive stages in the development of scab lesions. A photomicrograph of the lesion on the upper left apple is shown in Plate VIII, Fig. 6. Photograph made on July 1, 1908. Natural size*

FIG. 2.— *Showing the dwarfing effect of a single scab lesion on the side of an apple. Photograph made by Fisher, August 7, 1912. Natural size*



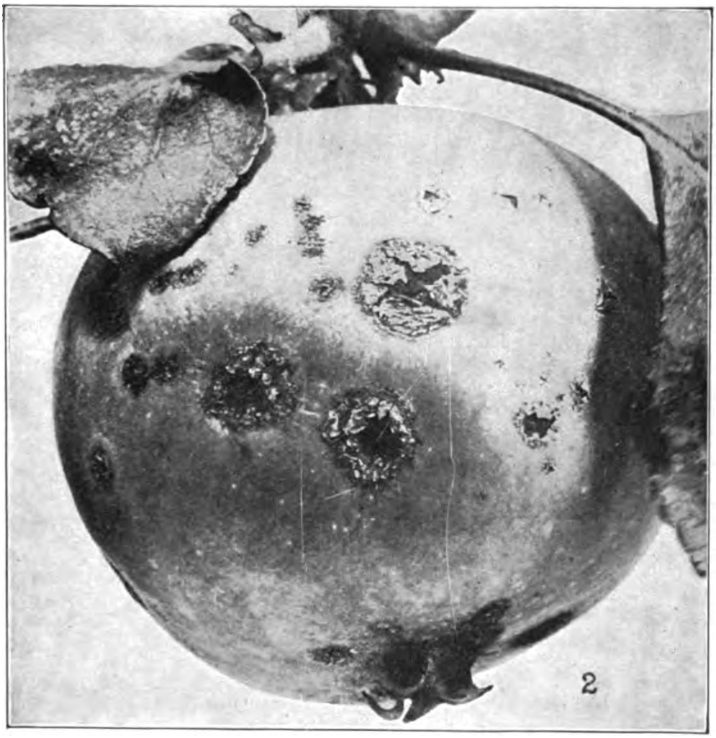


PLATE VI. FIG. 1.— *Scab lesions on fruit. Late, secondary infections are becoming prominent. Photograph made in the autumn of 1909. Natural size*

FIG. 2.— *Showing the action of the scab fungus in lifting the cuticle of the apple, thus allowing evaporation. Photograph made by Whetzel, July 31, 1906. Enlarged twice*

PLATE VII. FIG. 1.— *Pear scab lesions on leaves and pedicels. Pedicel infection is equally common on apple, but cannot be shown so well in photograph because of dense growth of hairs. In the orchard from which this twig was taken, practically no fruit set because of the attack on the pedicels. Photograph made on June 1, 1909. Natural size*

FIG. 2.— *Fruit pedicels and foliage severely infected at an early stage with the scab fungus. The apple in the upper right corner not so severely attacked. The fruit will never mature. Photograph made on August 15, 1908. Somewhat reduced*

equivalent to $48.50 an acre. Stevens and Sherman (1903) state that one grower reports an increase of $1000 in value of his crop due to spraying, at an outlay of $125 to $150; and that in the State of Illinois apple scab is estimated to have caused $6,000,000 damage in one year, or sixty per cent of the total loss through all enemies. Marlatt and Orton (1906) state that the loss from scab amounts to many million dollars each year. Scott and Quaintance (1907) estimate that scab often affects fifty to seventy-five per cent of the fruit over wide areas, and not infrequently causes total failure of the crop by killing the young fruit when in blossom or soon after. Gossard (1908) estimates a net profit of $3 to $7 for each tree, due to spraying for control of insects and disease, at a cost of 30 to 50 cents for each tree.

Estimates of loss in New York

Some interesting figures in regard to the importance of scab disease, as shown by the gain due to spraying apple orchards, are to be found in the reports on orchard surveys of Orleans and Niagara counties. Warren (1905) reports an average gain of $47 an acre, in 1904, in orchards sprayed three times over those not sprayed. This is included in a study of 564 orchards containing 4881 acres. Since it was thought that other forms of neglect might be correlated with that of omitting the spray, another count was made including only those orchards that were well cared for in other ways. The difference in this case was $81 an acre in favor of orchards sprayed three times. Evidently, then, the profit from spraying well-cared-for orchards is greater than that from spraying those otherwise neglected. This is what should be expected, since trees properly cared for are better able to produce a larger quantity of fruit than those not well cared for. The cost of spraying was estimated at $6.77 an acre, leaving an average net gain of $40.23 including all orchards and of $74.23 including only orchards otherwise well cared for.

Here, of course, it is impossible to separate the percentage of gain due to the control of scab from that due to the control of the codling moth, since the disease and the insect are controlled by a combination spray. An attempt was made to correlate the percentage of scab with the yield of fruit and the income for each acre. It was found that orchards having no scab to 5 per cent of scab gave an average income of $143 an acre, with a yield of 382 bushels; while those having 76 to 100 per cent of scab

(1903) Stevens, F. L., and Sherman, Jr., Franklin. Insect and fungus enemies of the apple, pear, and quince, with methods of treatment. North Carolina Agr. Exp. Sta. Bul. 183:66.
(1905) Warren, G. F. An apple orchard survey of Orleans county. Cornell Univ. Agr. Exp. Sta. Bul. 229:478.
(1906) Marlatt, C. L., and Orton, W. A. The control of the codling moth and apple scab. U. S. Agr. Dept. Farmers' bul. 247:12.
(1907) Scott, W. M., and Quaintance, A. L. Spraying for apple diseases and the codling moth in the Ozarks. U. S. Agr. Dept. Farmers' bul. 283:20.
(1908) Gossard, H. A. Spraying apples. Ohio Agr. Exp. Sta. Bul. 191:103-125.

gave an average income of only $88 an acre, with a yield of 248 bushels. This shows an apparent loss of $55 an acre where scab was abundant. It is probable, however, that the scabby orchards were unsprayed, and therefore suffered from the codling moth also. It is seen likewise from the figures given that these pests reduced the quantity of the yield 134 bushels an acre.

Cummings (1909) made similar estimates in his survey of Niagara county. Here unsprayed orchards gave an average yield of 261 bushels with an average income of $45 an acre, while three sprayings resulted in a yield of 577 bushels and an income of $171 per acre; a gain in yield of 316 bushels and in income of $126 an acre.

Cummings finds that there are in Niagara county about 24,190 acres in apples, and on this acreage about one fifth of the orchards are unsprayed. From this it may be estimated that the loss in the 4838 acres of unsprayed orchards in Niagara county would aggregate $609,588. An estimate similarly made from the figures already referred to by Warren for Orleans county shows that the loss suffered by unsprayed orchards in that county during the season of 1904 was about $287,616.

These are apparently very moderate estimates. Only the difference between orchards unsprayed and those sprayed three times was considered. Many orchards were ineffectively sprayed; they also suffered much loss and were not included in these estimates.

Taking Orleans county as a basis from which to work, the writer has attempted to estimate roughly what may be the total annual loss due to neglect of spraying in New York State and in the United States. As shown above, the loss in Orleans county in 1904 was $47 an acre. According to the census of 1900 there were in New York State at that time 15,054,832 apple trees of bearing age. Warren found that there are, on an average, slightly more than forty trees per acre, from which it may be estimated that there were about 376,370 acres of apple orchards in the State. Cummings found one fifth of the orchards in Niagara county unsprayed. Since that is one of the most progressive fruit-growing counties in New York, there is no doubt that it would be a conservative estimate to say that one fifth of the orchard area of the State is unsprayed, making a total of 75,274 acres on which a loss of $47 an acre would be suffered. This gives $3,537,878 as an estimate of the annual loss to this State through neglect of spraying. This estimate represents only the loss where no spraying is done. Many thousands of acres are ineffectively sprayed, and if the loss on these could be estimated it would add much to the aggregate.

(1909) Cummings, M. B. Apple orchard survey of Niagara county. Cornell Univ. Agr. Exp. Sta. Bul. 262:277-320.

Figuring on a similar basis for the United States, it is found in the same census that there were 201,794,764 apple trees on 5,044,869 acres. One fifth of this acreage gives 1,008,973.8 acres of unsprayed orchard, on which the loss at $47 an acre would amount to $47,421,768.60.

These estimates are based on by far the lower of the figures showing the average loss found to exist in the two cases cited above. According to figures of Cummings for Niagara county, in 1905 there was a gain of $126 an acre in the income from sprayed over that from unsprayed orchards. If this amount is considered as representing the average loss through neglect of spraying, the figures given here would be increased very materially. The writer has chosen the more conservative estimate, however, and believes he is safe in stating that New York alone loses over three million dollars annually through this one form of neglect on the part of its apple-growers, and that a corresponding loss of over forty-five million dollars is suffered by growers throughout the United States.

It is of course impossible to determine what proportion of this loss is due to scab. In the northern States scab is the all-important fungous disease of the apple and is the cause of a large proportion of the loss; while in some of the more southern States other diseases, such as bitter rot, blotch, and the like, outrank scab in importance. While the codling moth is generally distributed throughout the United States and is very destructive, a large percentage of wormy apples are also scabby and the disease alone would be responsible for great loss even if there were no codling moth.

Nature of the loss

Ordinarily the reduction in quality of scabby apples is considered to be the main cause of loss. This, while it is important, is only one of the several factors. It will be shown later that early scab infection, if not controlled, in some years almost entirely prevents the setting of fruit; it also very materially reduces the size of individual apples, while a single lesion retards growth on the affected side and causes unsymmetrical development (Plate V, Fig. 2). The unmistakable dwarfing effect has been apparent in experimental work during two epidemic years of apple scab, when it was noticed that apples from unsprayed trees were uniformly smaller than those from sprayed trees. Green (1891) determined that there was a loss in size of fifty per cent on scabby fruit as compared with sound fruit.

A fourth important factor of loss to be considered is the effect on the keeping qualities of the fruit. This effect is indirect, in that the disease furnishes a point of entrance for *Cephalothecium roseum*, the pink-rot organism, *Penicillium expansum*, the brown ripe-rot fungus, *Sphaeropsis malorum*, the black-rot fungus, and other organisms.

(1891) Green, W. J. The spraying of orchards. Ohio Agr. Exp. Sta. Bul. 4:9: 193–212.

In addition to the immediate effect on the crop of the current year, there is doubtless, in case of severe leaf infection, a devitalizing effect on the tree as noted by Bailey (1895, pp. 13–14). To some degree this prevents the formation of fruit buds for the following year and hinders the normal wood growth which is the basis for future crops.

Loss of fruit set due to the disease

The majority of apple-growers have believed for years that the occurrence of cold rains during the blossoming period is the cause of failure of fruit to set. There is ample evidence, however, that the scab disease occurs abundantly on the pedicels in certain years — as in 1910 — and causes the blossoms or the young fruit to fall (Plate VII, Figs. 1 and 2, and cover-page figure). It is even claimed by Reddick (1913) that cold rains at blossoming time are not a factor in the setting of fruit, but that the scab disease is the factor involved. The following instances may be cited as showing that destruction of the blossoms and the young fruit by scab furnishes an important source of loss, which is often overlooked because of the inconspicuous character of the disease at this stage or is attributed to various causes such as poor pollination, bad weather, and the like:

A general failure of the apple crop apparently due to this cause is noted by Bailey (1895) to have occurred during the summer of 1894. In regard to the cause of this failure Bailey writes (on page 20 of the bulletin cited): "I have visited over twenty orchards in the western part of the State this year in which there were large crops of excellent quality, but all of these had been sprayed with paris green or bordeaux mixture, or both, all of them were pruned and the land was in 'good heart.'" In general the orchards were almost barren in that year, and the smallness of the crop was usually in proportion to the degree of neglect to which the orchards were subjected. In another place Bailey states (on page 10): "But the immediate cause of most of our apple failures of the last few years, is undoubtedly the apple scab fungus." Again (on page 18): "The best proof that the apple scab fungus is the immediate cause of the greater part of the apple failures of western New York is afforded by the fact that thorough spraying with bordeaux mixture is usually followed by a great increase in the productiveness of the orchard." While it is not stated here just how the disease so greatly decreased the productiveness of the orchards, there is no doubt that the decrease was brought about principally by the occurrence of scab on the pedicels of the blossoms or the young fruit at an early stage, causing them to fall.

(1895) Bailey, L. H. The recent apple failures of western New York. Cornell Univ. Agr. Exp. Sta. Bul. 84: 1–34.
(1913) Reddick, D. The apple scab situation. West. New York Hort. Soc. Proc. 58: 86–90.

Lodeman (1895) cites an instance in which the crop was entirely destroyed by this form of attack, as shown by the fact that unsprayed trees bore no fruit while there was a large crop on trees properly sprayed.

Marlatt and Orton (1906) state that "the yield of fruit per tree is greatly lessened whenever scab is present: (1) by the premature dropping of young apples, due to the attacks of the scab fungus on flowers, stems, and fruits soon after the blossoms fall; (2) by the smaller size of the scabby apples that mature; and (3) by the loss, just before picking, due to the fact that scabby fruit does not cling well to the tree."

Scott and Quaintance (1907) note that scab not infrequently causes total failure of the crop, by killing the young fruit when in blossom or soon after.

Gossard (1909) reports that scab disease caused a large proportion of the young fruit to fall from unsprayed Winesap trees almost as soon as it had set.

Taft and Wilken (1909), in their report for 1908, make the following statement: "If the early spraying was done at the proper time, the work of the fungus which attacks the blossom stem and causes the blossom to drop was prevented."

Selby (1910) states that scab often causes the young fruit to fall, and that often this falling or failure of the fruit to set, which is attributed to frost injury or poor pollination, is really due to scab.

Pink rot following scab

This is another important factor for consideration in connection with the causes of loss due to apple scab. The first serious outbreak of pink rot apparently occurred during the season of 1902 and was reported almost simultaneously by Eustace (1902) of Geneva and by Craig and Van Hook (1902) of Cornell University. The fungus causing the disease, *Cephalothecium roseum* Cda., was found to attack the apple almost entirely through wounds in the cuticle and in the epidermis caused by scab. The fungus had formerly been considered a saprophyte, although Aderhold (1899) had reported a case in which it caused rot of pears following scab infection.

(1895) Lodeman, E. G. The spraying of orchards. Cornell Univ. Agr. Exp. Sta. Bul. 86:119.

(1899) Aderhold, Rudolf. Arbeiten der botanischen abteilung der Versuchsstation des Kgl. pomologischen Instituts zu Proskau. Centbl. bakt. 2:5:522.

(1902) Eustace, H. J. A destructive apple rot following scab. New York (Geneva) Agr. Exp. Sta. Bul. 227:367–389.

(1902) Craig, John, and Van Hook, J. M. Pink rot, an attendant of apple scab. Cornell Univ. Agr. Exp. Sta. Bul. 207:157–171.

(1906) Marlatt, C. L., and Orton, W. A. The control of the codling moth and apple scab. U. S. Agr. Dept. Farmers' bul. 247:12.

(1907) Scott, W. M., and Quaintance, A. L. Spraying for apple diseases and the codling moth in the Ozarks. U. S. Agr. Dept. Farmers' bul. 283:20.

(1909) Gossard, H. A. Apple spraying in 1908. Ohio Agr. Exp. Sta. Circ. 95:4.

(1909) Taft, L. R., and Wilken, F. A. Annual report of the South Haven sub-station for 1908. Michigan Agr. Exp. Sta. Spec. bul. 48:16.

(1910) Selby, A. D. A brief handbook of the diseases of cultivated plants in Ohio. Ohio Agr. Exp. Sta. Bul. 214:371.

According to the three authors first named above, apple scab had been very common during the summer of 1902. Late in the season, in August and September while the fruit was yet on the trees, it was observed, as stated by Eustace, that on some of the scab spots there appeared a white or pinkish, mildew-like growth. A little later this growth produced a brown, sunken, bitter rotten spot. On very scabby apples these spots soon coalesced and the fruit became a mass of decay.

Some rot develops in the fruit while it is on the trees, as stated above, but the greater destruction occurs soon after the fruit has been stored or while it is in piles on the ground. The occurrence of this disease has been common to a greater or less degree since 1902. During the season of 1910 considerable pink rot developed in many sections of the State where scab was not kept well under control.

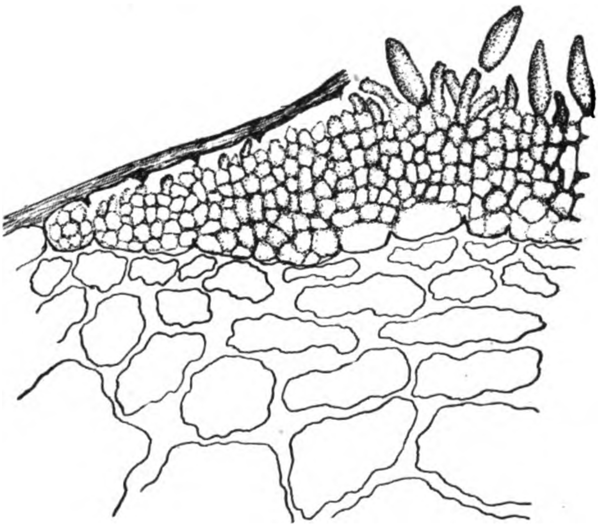


FIG. 182.— *Conidial stage of Venturia inæqualis. The section through a scab spot shows the fungus stroma located beneath the cuticle and in the epidermal cells, conidiophores, and the development of conidia. The growth of the fungus, especially the development of conidia, lifts the cuticle. A few of the conidiophores show the scars where spores were developed earlier in the season. (See also Plate VI, Fig. 2.) Camera lucida drawing*

ETIOLOGY

Morphology

The apple-scab disease is caused by the fungous pathogen *Venturia inæqualis*. The mycelium of the fungus is in some cases hyaline when young, but it soon becomes tinted and varies from olivaceous to reddish brown. It is septate, branches very irregularly, and is subject to modifications as influenced by environment, varying particularly in the different stages of the life cycle of the fungus. The hyphæ vary from 3 to 5 μ in diameter in the living host, but in the dead leaves they may be as much as twice this size (Plates IX and X). In the living host the mycelium will be found, in the early stages on leaves, confined to a region between the cuticle and the epidermal cells; on the fruit the epidermal cells are attacked and usually destroyed.

Previous to the formation of conidia this subcuticular mycelium divides

into one or more layers of densely packed, rounded, and at first hyaline cells (stroma), from which the conidiophores are produced (Fig. 182). The outer layers later take on a brownish tint. On the leaves this stroma may consist of only one layer of cells, but more than one layer is likely

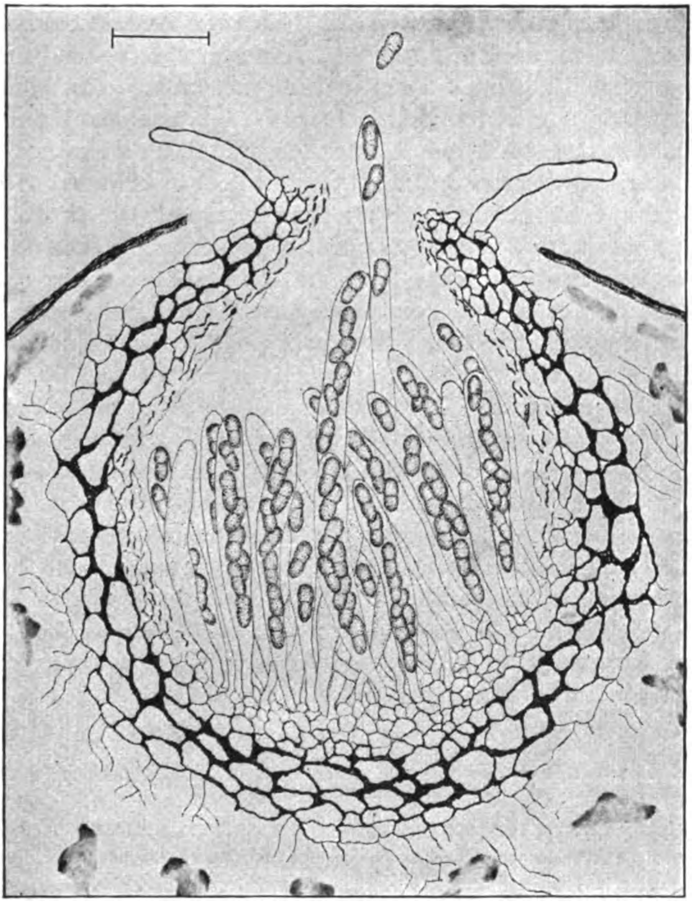


FIG. 183.— *Mature perithecium of Venturia inæqualis. The section shows the method of formation of asci, mature ascospores, the method of ejection of ascospores, and the bristles that sometimes occur about the ostiole. Outlined with a camera lucida*

to occur over the veins or the firmer parts of the leaves. On the fruit the number of layers is much greater, due apparently to the fact that the thicker cuticle offers a greater resistance which is not overcome until the time for the formation of more cells has elapsed. This resistance is apparently overcome partly by means of a solvent action of the fungus

(as shown in Fig. 182, where the cuticle is found to have been eaten away from beneath, directly over the subcuticular mycelium), and partly by the pressure exerted which finally pries the cuticle loose. The conidiophores that arise from these cells are reddish brown in color and while young are somewhat ovate in form. They have an inner hyaline wall which protrudes from the apex to form the spore. At first the spores are hyaline and are rounded in a sac-like manner at the free end, but later they become reddish olive-colored and are mostly lanceolate but somewhat irregularly so and variable in form. They are mostly unicellular, but in the later stages a septum is often formed. They are rather variable in size, measuring 12 to 22 μ in length by 6 to 9 μ in breadth. The form and general appearance of the conidiophorė changes with its age and the number of conidia that it has produced. The older conidiophores assume a more or less irregular form, showing a distinct knee and a change in the axis of growth at the point where each spore was borne. They are usually unicellular, but sometimes old conidiophores become septate.

The perithecia are imbedded in the tissue of the leaf, usually protruding sufficiently to form a small dome-shaped pimple (Fig. 183) which is sometimes large enough to be easily visible to the naked eye but at other times only discernible by the aid of a lens. They are spherical or subspherical, 90 to 160 μ in diameter, with a somewhat beak-like projection at the ostiole. Six or more simple tapering bristles 25 to 75 μ in length sometimes surround the ostiole. The perithecial wall is dark olive-green to brown in color, with polygonal reticulations. The asci are oblong to clavate, often somewhat curved, 55 to 75 μ by 6 to 12 μ, without paraphyses. The ascospores are olive-brown, two-celled, with the upper cell somewhat broader than the lower, 11 to 15 μ by 5 μ. There are eight ascospores in each ascus.

Nomenclature

As early as 1819 Fries (1819) applied the name *Spilocæa Pomi* to the conidial stage of the apple-scab fungus. Wallroth (1833) described the same fungus under the name *Cladosporium dendriticum*. Fuckel (1869) transferred the fungus to the genus Fusicladium and called it *Fusicladium dendriticum* (Wallr.) Fckl. Cooke (1866) described the ascigerous stages of the forms occurring on both apple and pear as *Sphærella inæqualis*. Clinton (1901) notes that Winter seems to have been the first to place the species under the genus Venturia, since the specimens on apple leaves distributed in 1880 in von Thümen's Mycotheca Universalis No. 1544 are

(1819) Fries, Elias. Spilocæa Pomi Fr. Nov. fl. Suec. 5: 79.
(1833) Wallroth, F. G. Cladosporium dendriticum W. Fl. crypt. Germ. 2:4:169.
(1866) Cooke, M. C. Sphærella inæqualis Cke. Journ. bot. 4: 248–249.
(1869) Fuckel, L. Fusicladium dendriticum (Wllr.). Symb. myc., p. 357.
(1880) Winter, Georg. Venturia inæqualis Wint. Myc. uni., von Thümen, no. 1544.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67: 123.

PLATE VIII.— *Perithecial stage of Venturia inæqualis*

FIG. 1.— *Photomicrograph of the under surface of a leaf thickly dotted with perithecia of Venturia inæqualis*

FIG. 2.— *Same as Fig. 1, except that dehiscence has occurred in a circumscissile manner leaving cavities in the leaf. The saucer-shaped base of the perithecium was found in some of these*

FIG. 3.— *Same leaf as is shown in Fig. 1, showing perithecia on upper surface of the leaf*

FIG. 4.— *Photomicrograph of a perithecium in action. The perithecium was pricked out of the leaf with a needle and was placed in a drop of water on a glass slide. The photograph was made while spores were being discharged*

FIG. 5.— *Photomicrograph of a free-hand section through a perithecium. This shows the elongation of asci that occurs when moisture is present*

FIG. 6.— *Photomicrograph of the very young scab spot shown in the upper left apple in Plate V, Fig. 1. Shows how the cuticle is lifted by the growth of the fungus*

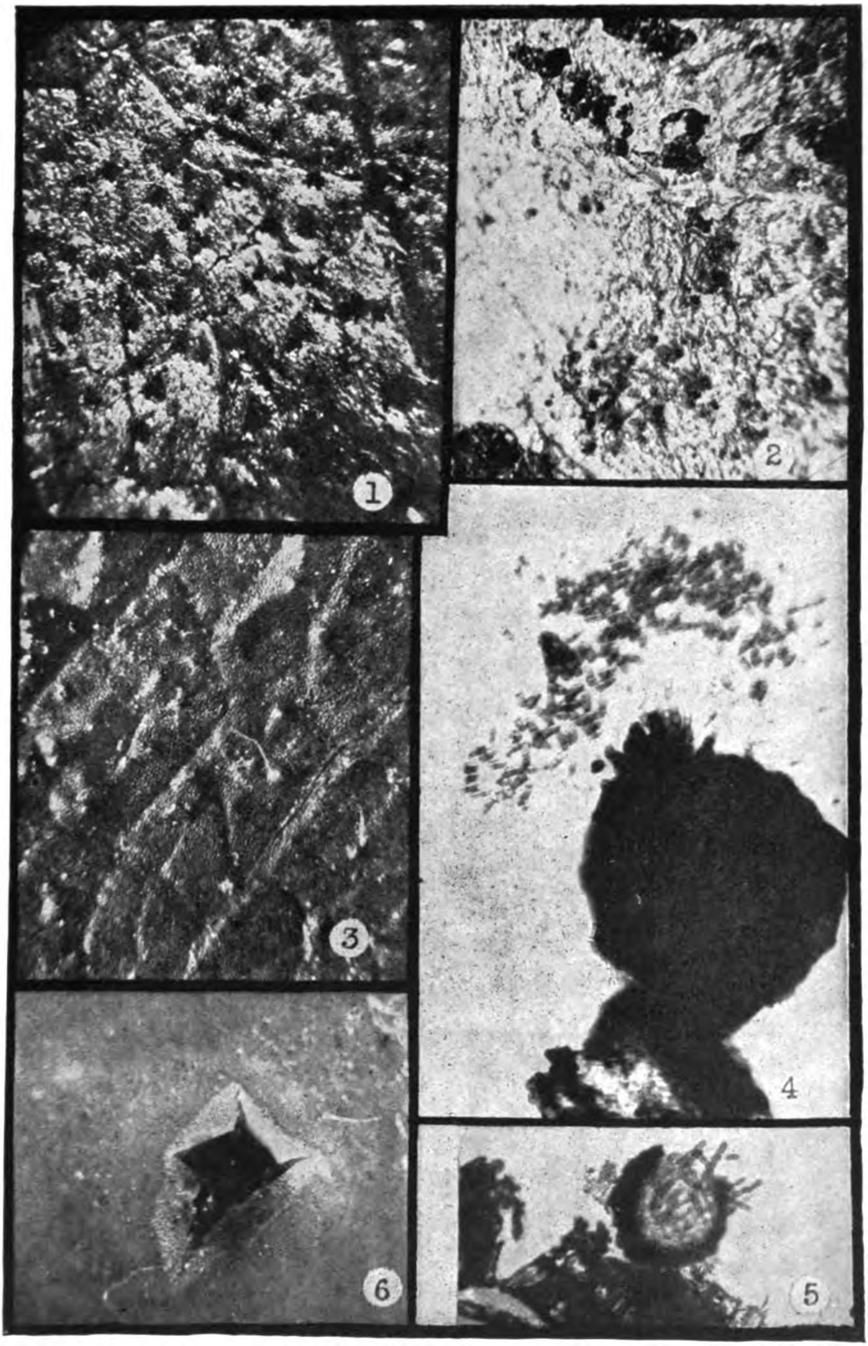


Plate VIII.— *Perithecial stage of Venturia inæqualis*

PLATE IX.— *Germinating ascospores of Venturia inæqualis. Ascospores discharged from perithecia in old leaves were caught on agar plates and allowed to germinate*

FIG. 1.— *Average germination after twelve hours*
FIG. 2.— *Average germination after thirty-one hours*
FIG. 3.— *Average germination after forty-two hours*

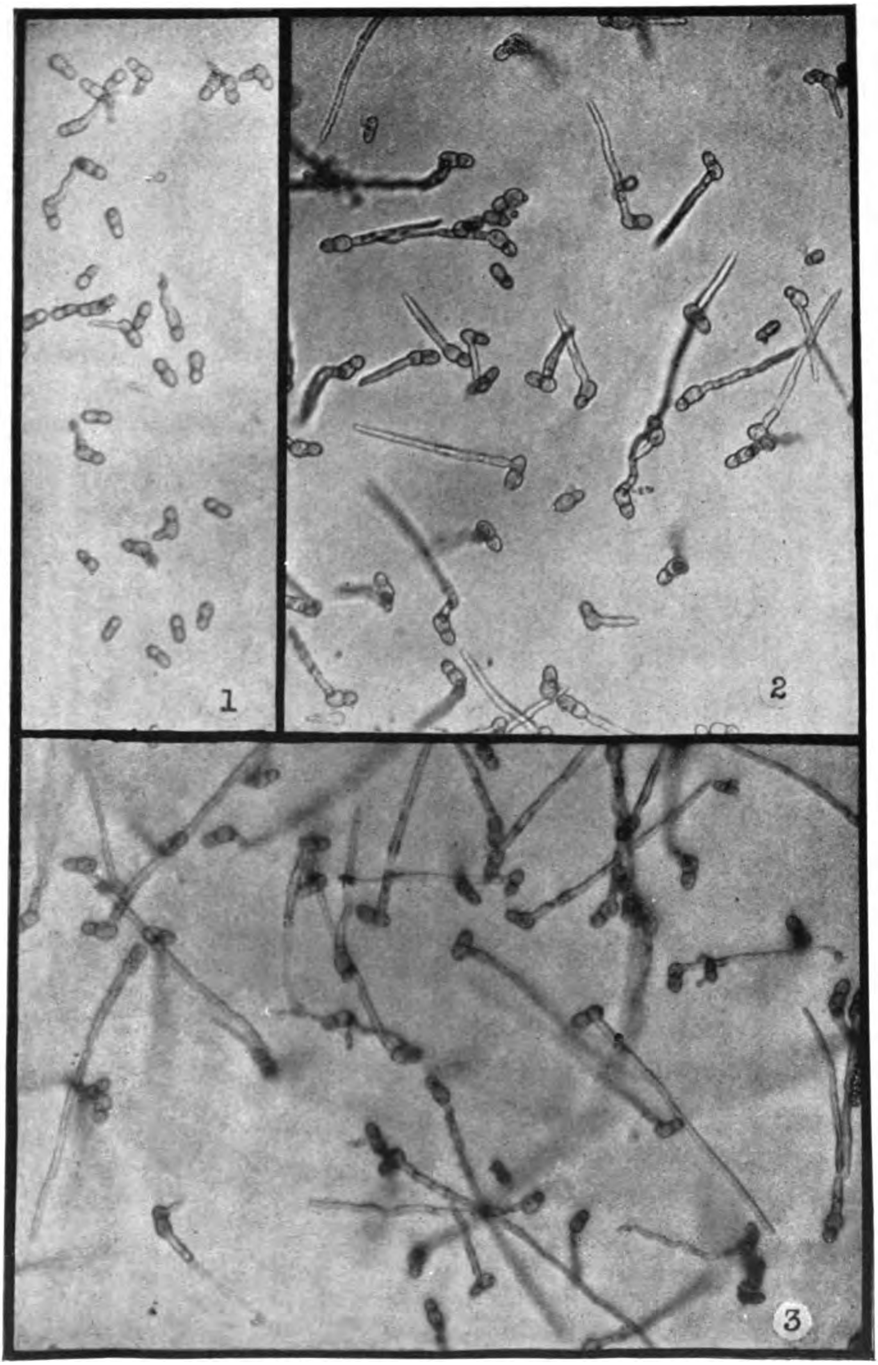


PLATE IX.— *Germinating ascospores of Venturia inæqualis*

PLATE X.— *Same as Plate IX*

FIG. 1.— *Average germination after fifty-one hours*
FIG. 2.— *Average germination after seventy-two hours*
FIG. 3.— *Average germination after one hundred and twenty hours*
FIG. 4.— *Mycelium and spores more highly magnified*

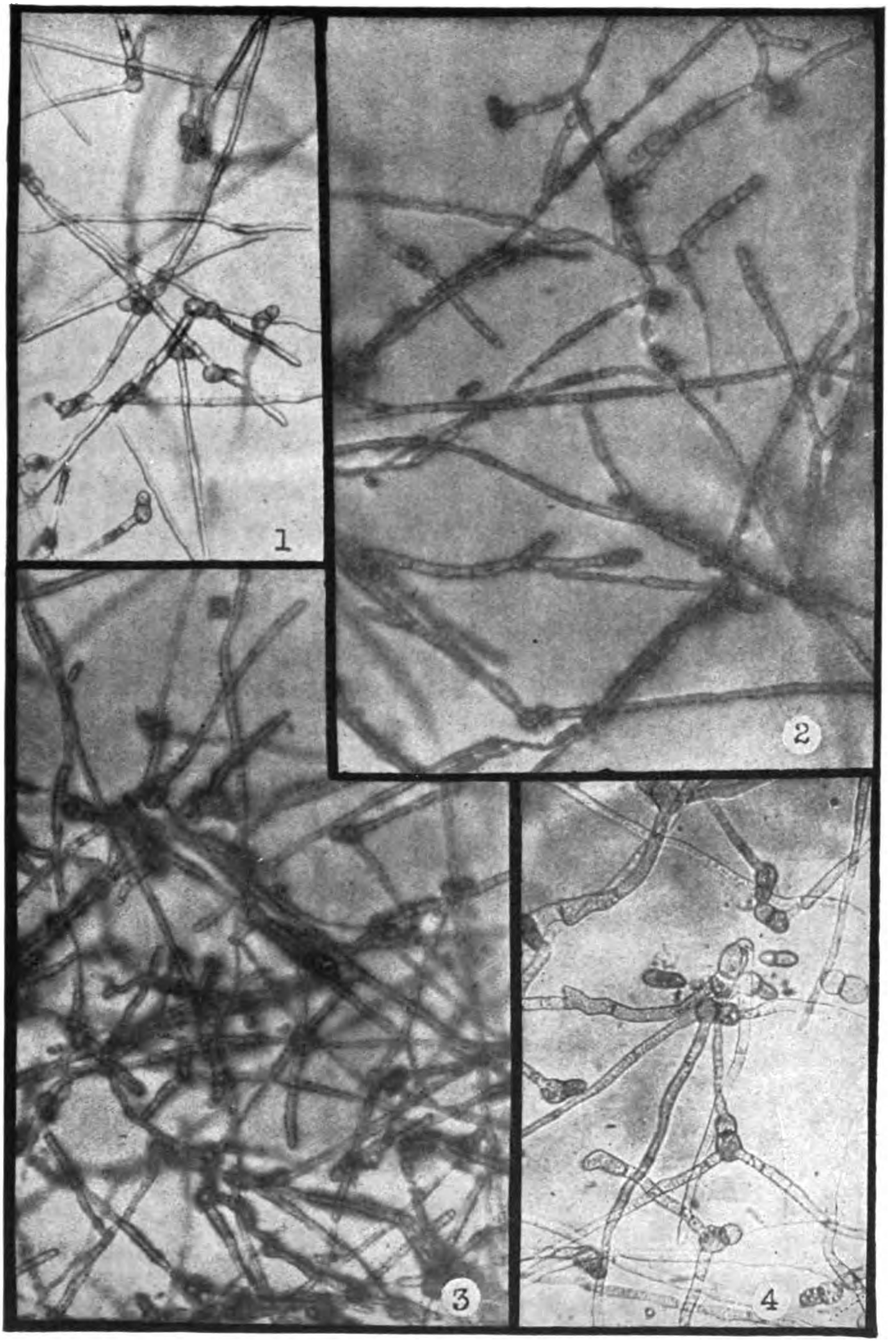


Plate X.— *Germinating ascospores of Venturia inæqualis*

called *Venturia inæqualis* Wint. in litt. Aderhold (1897) also places this fungus in the genus Venturia, calling it *V. inæqualis* (Cke.) Ad., apparently not knowing that it had been listed previously by Winter.

From the work of Aderhold (1894) it is known that *Fusicladium dendriticum* is merely a conidial stage of a perithecia-forming fungus of the genus Venturia. According to present rules of nomenclature, then, the fungus should be known as *Venturia inæqualis* (Cke.) Wint.

Relationships and host plants

Aderhold (1900) states that *Fusicladium dendriticum* occurs on many *Pyrus* species of the *Malus* group (*P. spectabilis* Ait., *P. Kaido* Sieb., *P. floribunda* Sieb., *P. baccata* L., *P. prunifolia* Willd., *P. rivularis* Hook., *P. divica* Mnch.). A variety, Aderhold states, is found to occur on species of Sorbus and apparently also on Crataegus. In regard to the two last named, however, Aderhold was convinced by later experiments that these forms are entirely distinct from *F. dendriticum*.

Previous to later work of Aderhold (1903) the Fusicladia on Crataegus and Sorbus were supposed to be varieties of the apple-scab fungus, and thus capable of infecting the apple. In this later article the author records cultural experiments in which the Venturia found on Crataegus was shown to produce the typical conidial stage of *Fusicladium crataegi* Adh., a species distinctly different from *F. dendriticum*. Aderhold concludes that the fungus on Crataegus is entirely distinct from that on the apple, and that there need be no fear of Crataegus as a means of infecting the apple. In the same article he records experiments designed to determine whether *Fusicladium orbiculatum* Denn. or *Sorbus torminalis*, which is closely related to *F. dendriticum* morphologically, can infect the apple. Inoculations were made with cultures derived from the form found on Sorbus, with the result that abundant infection followed on *S. torminalis*, but none on apple trees, on *S. domestica*, or on *Pyrus chamaemespilus*. Aderhold states, however, that negative proof is not entirely decisive and that the experiments should be repeated in order to obtain a positive decision. The writer has not attempted cross-inoculation.

Life history

Perithecial stage

It is well known to pathologists that *Venturia inæqualis* has two distinct stages in its life cycle. The writer's observations on the life history of

(1894) Aderhold, Rudolf. Die perithecienform von Fusicladium dendriticum Wal. (Venturia chlorospora f. Mali). Deut. Bot. Gesell. Ber. 12:338–342.
(1897) Aderhold, Rudolf. Revision der species Venturia chlorospora, inaequalis, und ditricha autorum. Hedw. 36:81.
(1900) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Centbl. bakt. 2:5:593–595.
(1903) Aderhold, Rudolf. Kann das Fusicladium von Crataegus und von Sorbus-arten auf den apfelbaum übergehn? Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw. Arb. 3:436–439.

the fungus began with a study of the perithecial stage during the spring of 1908. L. F. Strickland, who was at that time a special student in the Department of Plant Pathology at Cornell University, located a crab-apple tree on the campus which furnished abundant material for a study of the ascigerous stage. After having become interested and having learned what to look for, the writer had no difficulty in finding perithecia in old leaves under apple trees in other localities. Many investigators appear to have had considerable difficulty in finding this stage of the fungus; but the writer is convinced, from the experience of three seasons, that it can be found easily almost any spring following a year of foliage infection if looked for carefully at the right time. Material in abundance was found easily in 1909, 1910, and 1911.

The perithecia appear most abundantly on the exposed surface of the leaf as it lies on the ground. They are often not easily discernible with the naked eye, but appear under a lens as small, dome-shaped pimples on the surface of the leaf. They are sometimes confused with the fruiting bodies of other fungi which are very similar in external appearance to the perithecia of Venturia and which are frequently more abundant than the latter. However, by one who is familiar with their appearance they can usually be distinguished from other forms on examination with a hand lens (Plate VIII, Figs. 1, 2, and 3); the pimples commonly have more of a dome-like form and are plumper than those of other fungi that are likely to be confused with them.

Development of perithecia

The perfect stage of the fungus begins to develop in fall or early winter. After the scab-infected leaves have fallen and decay has set in, the mycelium, which during the summer does not penetrate deeper than the epidermis, permeates the entire leaf tissue and sometime during the fall or winter begins to form perithecia. This winter development has not been studied very carefully, but a few notes were made at various intervals during the winter and spring of 1908–1909. Scabby leaves were brought in during the latter part of November, 1908, and parts of these leaves were cooked in potassium hydroxid. This did not make it possible to separate the epidermis from the underlying tissue, as had previously been the case. It seemed as if the mycelium had already permeated the tissue and, as it were, sewed the epidermis fast.

On February 26, 1909, leaves were examined and found to contain immature perithecia. At this date the asci were filled with a homogeneous mass of protoplasm which had not yet become differentiated to form spores. When the perithecia were pricked out in water these immature asci would push out through any wounds in the perithecium, but

they were not seen to push out through the ostiole which was probably not yet open. In some cases there was so much expansion of the asci, due to the absorption of water which was evidently admitted through the wounds, that dehiscence occurred, bursting off the upper half of the perithecium in a manner similar to that to be described as occurring in the case of mature perithecia. It would seem, then, that even at this early date the immature asci have the ability to absorb water and exert a pressure similar to that exerted later by means of which the discharge of spores is brought about. It is evident that in nature this premature action is in some way prevented.

Some of the leaves brought in on February 26 were kept in a moist chamber in the laboratory until March 20, when they were examined. The spores had been formed and some were evidently ripening at that date, since they were somewhat brown. Some shooting of spores also occurred. This, it will be noted, is almost one and one half month earlier than the same stage of development was reached under natural conditions; in leaves from out of doors the asci were much less mature at this date. In some asci the protoplasm had just begun to differentiate to form spores and the few spores formed were still hyaline; in other asci the protoplasm still existed as a homogeneous mass in the ascus. The perithecia were small and inconspicuous and were likely to be overlooked. It was especially noticeable during 1910 that the perithecia remained inconspicuous until near the end of their maturity, when they enlarged somewhat. It was difficult to find infested leaves until the apple blossoms were about ready to open.

Clinton (1901) found signs of perithecial formation in sections of fallen leaves made as early as October, and could occasionally connect these perithecia by mycelial thread with the subcuticular mycelium. He notes that the perithecia usually occur on the lower side of the leaf, especially along the veins, and believes that they usually originate from a late infection on the lower side of the leaf. In the writer's observations during the past three seasons, perithecia have been found to occur abundantly on both sides of the leaf. They seem to develop mostly on the side that faces upward as the leaf lies on the ground. There appears to be a negatively geotropic tendency.

Time of maturity of ascospores

In nature the ascospores usually begin to mature at or about the time when the apple blossoms are ready to open. In 1908 mature spores were found on May 4 and in 1910 on May 1; the blossoms were about to open in each case. The exact date for 1909 is not available but it did not differ

(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:121.

materially from those given for 1908 and 1910. The ascospores do not all mature at one time and the ripening process may continue for about one month. These points are discussed more in detail and the results of observations are tabulated elsewhere in this bulletin.

Discharge of ascospores

Turning now to a more detailed study of the mature perithecium, some interesting phenomena are found. During the spring of 1908 an attempt was made to study the mode of discharge of the ascospores. Several methods of observing this phenomenon were employed. First, leaves containing perithecia were sectioned and the discharge of spores from the asci in water on a glass slide was observed under the microscope. This was rather an unnatural condition, since the sectioning usually cut the perithecia open thus exposing the asci to free access of the water. A more natural method seemed to be to soften the leaves and prick out the perithecia with a needle, place them in water on a slide, and observe their method of discharge. A photomicrograph of a perithecium thus treated is shown in Plate VIII, Fig. 4. Even with this method the conditions are somewhat abnormal, since it is impossible to prick out the perithecia without inflicting certain wounds which seem to admit water prematurely and thus premature extrusion of the asci and dehiscence of the perithecia are sometimes caused. From a study of this nature, however, accompanied by a study of spore discharge *in situ* on the leaf, much can be learned.

It was noticeable throughout the study that any wounding of the perithecium induces more rapid discharge of ascospores and even induces discharge of spores from perithecia that are immature. It would seem that the expansion and extrusion of the asci and the discharge of spores is due to the absorption of water by the asci, and that premature discharge of the spores is prevented only by the fact that the perithecia in some way prevent premature or too rapid admission of water.

Another point of interest along this line is that when the perithecia are wounded and the consequent abnormally rapid extrusion of the asci takes place, it sometimes happens that the number of asci thus forced into action at one time is greater than can be accommodated by the ostiole. Consequently a greater pressure is exerted than the perithecium can withstand, and the upper half is burst off thus exposing all the asci at once.

This was first noticed in studying perithecia pricked out of leaves and placed in water on the slide. In many cases these perithecia would be seen to dehisce as described above. In Fig. 184 is shown a camera lucida drawing made at different stages of the above-described process. The dehiscence is always circumscissile, occurring nearer to the base than to

the ostiole of the perithecium, apparently just above the point of attachment of the asci so that the latter adhere to the basal part.

A subsequent examination of leaves containing perithecia revealed the fact that a circumscissile dehiscence similar to that observed under artificial conditions occasionally occurs also in nature. Certain leaves could be found in which the crowns of many of the perithecia had been burst off, carrying with them the adhering fragments of the epidermis of the leaf and leaving the saucer-shaped bases of the perithecia *in situ* in the

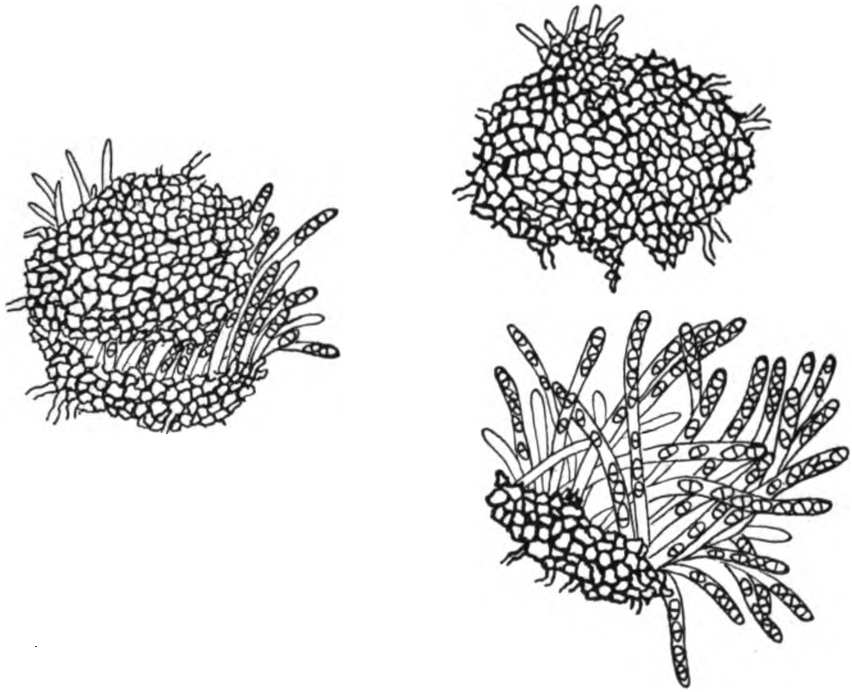


FIG. 184.— *Circumscissile dehiscence of the perithecium, showing two stages in the rupture of the same perithecium. Outlined with a camera lucida*

leaf. A photomicrograph of the surface of such a leaf is shown in Plate VIII, Fig. 2. This phenomenon was found to be fairly common in 1908 but has since been observed only occasionally. It is possible that some particular condition of the season of 1908 favored this method of spore discharge.

Clinton (1901) makes the following statement, which is suggestive when considered in connection with what is stated above: "When mature [perithecia] are more or less loosely imbedded in the leaf tissues and at the time of their disappearance infected leaves often show numerous small

(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:122.

holes where they have been imbedded." The writer has little doubt that the "small holes" thus observed were similar to those shown in Plate VIII, Fig. 2, and were the result of dehiscence as described above rather than of the mechancial removal of the entire perithecium.

McAlpine (1904), who studied this fungus in Australia, notes that "the perithecia or spore cases soon fall away from the dead leaves, so that by the middle of October scarcely a single one could be obtained from leaves still on the ground, though the minute holes showing where they had been were plainly visible." Here again it seems evident that these "minute holes" in the leaves were the result of such dehiscence. The perithecia are certainly not so loosely imbedded in the leaves that they fall out merely from their own weight.

Another method of studying ascospore discharge is to place glue-coated slides in an inverted position over moistened leaves containing perithecia. By this means a study was made in order to determine how high spores may be shot; how many may be discharged in a given time from a given area of leaf surface; how soon after wetting the leaves the discharge may begin; how long it may continue and how long a single perithecium may continue to discharge spores; and whether the continued discharge, covering a period of several weeks during the spring and early summer, is due to the ripening of new perithecia or of new asci in the same perithecium.

No spores were caught on slides placed higher than 1.1 centimeter above the leaf, and but few at this height. At .5 centimeter a large number were caught.

From a fragment of leaf 1 centimeter square 5630 spores were discharged in forty-five minutes. From this it is estimated that if the surface of the ground beneath trees set 40 by 40 feet apart were covered with old leaves well infested with perithecia, there might be 8,107,200,000 ascospores discharged for each tree in forty-five minutes in wet weather. Certainly this would be sufficient to account for abundant early infection, even though only a very small percentage of these ascospores would reach the trees and actually produce infection.

The discharge of spores begins very soon after the leaves are wet. Dry leaves were brought in and moistened and glue-coated slides were inverted above them. After five minutes the slides were removed and examined. A number of spores were found, showing that spore-shooting begins almost as soon as rain begins, or within five minutes after the leaves are wet.

In order to determine how long a single leaf or part of a leaf might continue to discharge spores if kept constantly wet, pieces of perithecia-bearing leaves were placed in a moist chamber under glue-coated slides and occasional examinations were made, new slides being supplied each time.

(1904) McAlpine, D. Black spot of the apple. Victoria Agr. Dept. Bul. 17: 10.

Four of these experiments were set up on May 21, 1908. On the next day spores were abundant on three slides and there were a few on the fourth. On the second day spores were abundant on one slide and there were a few on the others. On the third day they were abundant on one slide and there were a few on one other. The fourth day showed similar results. On the fifth day many spores could be found on the slide above one piece of leaf. On the tenth day a few spores had been discharged from the same specimen. On the eleventh day no spores were found.

These leaves were dried for eleven days and then rewet, in order to determine whether this might induce a reawakening of activities. The results were negative. No more spores were discharged from any of these leaves.

It is clear from this experiment, however, that under continuously wet conditions an uninterrupted discharge of spores can be expected for some time. Under these artificial conditions a single leaf continued to discharge ascospores abundantly for ten days. It is probable that in nature some leaves may be found that would continue even longer than this; and the fact that from some leaves operations would begin earlier than from others would lengthen the period still more. It is evident, then, that a rainy period sufficiently prolonged to exhaust the leaves of ascospores either temporarily or permanently would rarely, if ever, occur. It would seem probable, however, that a frequent succession of rainy periods would exhaust the supply earlier in the season by hastening the maturity and the discharge of ascospores. Judging from observations made during the spring of 1908, ascospore discharge continues for about one month or slightly longer. It was first noted on May 4, while leaves gathered on June 6 were found to contain only empty perithecia.

Further experiments were tried in order to determine whether the long-continued production of ascospores is due mainly to the continued ripening of immature asci in the same perithecium or to the ripening of immature perithecia. Pieces of leaves each containing a single perithecium were cut out with the aid of a razor and a dissecting microscope. These pieces were kept moist under a glue-coated slide, as described above. Thirteen perithecia were so treated, and in no case could it be found that spores were discharged continuously from a single perithecium for a longer period than one day. In one experiment including six perithecia, three were active on the first day and three others on the second day; the latter three were evidently not quite ripe on the first day. In another experiment including seven perithecia, two were active and for the first day only.

These experiments are not exhaustive. They seem to indicate, however, that individual perithecia mature at different times and thus extend the

period of ascospore discharge over one month or more in the spring; but that when discharge from a given perithecium begins, if kept constantly wet its entire contents are discharged within twenty-four hours.

Cultural characters of the fungus

Aderhold (1896) grew the fungus successfully on a number of artificial media; among these he mentions leaf and stem infusions of various plants, such as apple, pear, cherry, birch, syringa, and pink. He grew it also on fresh cucumber sap and on gelatin. The cultural characters were alike whether the fungus was grown from ascospores or from conidia.

Appressoria were formed, which were at first club-shaped but the clubbed ends of which later enlarged irregularly, somewhat in the form of hands with the fingers reaching down into the substratum. The appressoria became somewhat brown in color, and from them developed colorless hyphæ corresponding to the infection tubes that occur when germination takes place on the host plant. Voges (1910), in describing the formation of appressoria, notes the presence of a gelatinous envelope which he believes to be important as a means of anchorage.

One point of special interest noted by Aderhold is that cultures of the fungus in spring or early summer form but little mycelium and many spores; while cultures made on the same gelatin in the fall produce but very few spores and abundant mycelial growth. This he found to hold true whether cultures originated from conidia or from cultures obtained directly from the conidia from leaves in the fall. In the hundreds of cultures made during the two years, only one exception to this rule was observed. The phenomenon is attributed to a difference in the age of the generation. In fall the mycelium penetrates deeply into the tissues of the dead leaf, forming an abundant mycelial development which in spring results in the formation of perithecia. Aderhold is also of the opinion that the first generation of the fungus which develops from ascospores forms conidia abundantly and quickly at the expense of mycelial development. Then, on the approach of fall, the conidial formation is retarded and mycelial development is increased for the purpose of favoring the formation of perithecia.

Aderhold was not able to develop the perfect stage to maturity in artificial cultures. He states, however, that there appeared very abundantly in the cultures, from exhausted conidial formations, bodies which he says are doubtless to be regarded as young perithecia.

The writer experienced no difficulty in obtaining pure cultures of the fungus by dilution plates from conidia and by inverting plates of agar about one half centimeter above moistened leaves containing perithecia.

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25:888.
(1910) Voges, Ernst. Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 20:385–393.

In the latter case the ascospores when discharged were caught by the agar. Germinated spores were later transferred to tubes. It was noted that these ascospores did not germinate so quickly as did others placed in water, but they grew more vigorously later.

Artificial inoculations

Aderhold (1896), in carrying out infection experiments, tried several methods of marking the point of inoculation so as to avoid confusion with natural infection. He used india ink and several coloring matters for this purpose, but found nothing else so successful as surrounding the point of inoculation with Von Stahl's cocoa-butter-wax mixture. When the leaf was all dried before applying it and the ring was not made too narrow, this mixture adhered well, and, if not applied too hot, did not injure the leaf nor prevent germination of the spores.

The inoculations were made on the young leaves and on the fruit. From ascospores on leaves Aderhold obtained about thirty-three per cent infection and from conidia about twenty-three per cent. From conidia on fruit he had less success; only about eight per cent of the inoculations were successful. According to Aderhold's tables conidia taken from fruit or from artificial cultures were less successfully used than those taken from scabby leaves.

The method of infection was studied also. Aderhold observed that the germ tube usually enters directly over the junction of two epidermal cells and often where several meet, in a corner so to speak. It broadens slightly at the point of entrance and bores directly through the cuticle. It was not observed to enter through wounds. Aderhold observed not only that the germ tube can bore directly through the cuticle, but also that the conidiophores sometimes bore their way out from beneath the cuticle. In other cases the cuticle may be ruptured by pressure from the mycelial growth beneath.

Clinton (1901) considered outdoor work unreliable because of the abundant natural infection. Accordingly he used one-year-old or two-years-old seedlings planted in crocks indoors and grown at a temperature higher than that outside. These seedlings were inoculated and kept in moist chambers. Inoculations made in this way were not very successful. Branches were cut off and artificially inoculated indoors. The leaves dropped in two weeks and therefore no results were obtained from this method.

The writer's inoculation experiments were performed mainly during the spring of 1908. For most of this work ascospores obtained from dead

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25: 893.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67: 120.

leaves were used. It was desired to determine how readily ascospores may cause infection, what the period of incubation is, and how infection takes place.

Leaves containing an abundance of perithecia were chopped fine in water and this decoction was applied with a brush. The twigs were then inclosed in a moist chamber. This was made of a large test tube or a lamp chimney, having all openings closed with cotton and some moist cotton left inside.

On leaves inoculated on May 16, scab first appeared on May 24. The same leaves had been examined on May 23, when no infection was visible. It is evident that the period of incubation in this case was exactly eight days. By May 28 these leaves showed that many infections had taken place on each leaf (Plate II, Fig. 1), while only a few spots could be found on any uninoculated leaf. On May 31 ninety-eight distinct infections were counted on nine leaves that had been artificially inoculated, while only twenty-four infections could be found on twelve leaves from a branch that represented the most abundant natural infection found. There is no doubt, therefore, that the abundant infection was the result of inoculation. Further inoculations were made on May 26. By June 12 the leaves inoculated on May 26 were very badly infected. They had been examined three days previously and scab was not visible; its appearance, therefore, was rather sudden, and the period of incubation in this case must have been about fifteen days unless for some reason the infection did not take place as soon as the inoculation was made.

The writer would not like to infer, without further data, that the period of incubation increases in length as the season advances, but this may be possible. As the leaves become older and the cuticle thicker, a longer time may be required for the fungus to work its way out through the cuticle. This, however, is as yet only a suggestion. In each of the above experiments blossoms or young fruits were also inoculated, but they dropped before the time for the appearance of scab had arrived.

Artificial infection with conidia was also attempted. Both leaves and young fruit were inoculated with conidia from scabby leaves at three different dates — June 10, June 12, and June 15. The results were not nearly so striking as in the earlier experiments, when ascospores were used. A somewhat larger number of leaf infections followed than on the uninoculated leaves, but not enough more to permit safely the drawing of conclusions. Infection of fruit was not successful at this time.

In 1910 Rhode Island Greening and Baldwin apples were inoculated when almost full-grown. Conidia from scabby leaves were used and each apple was covered with moist cotton as soon as inoculated. Early in September a large proportion of the inoculated Rhode Island Greenings

showed late infection. On one apple nine spots were counted, several others had three to five spots, and about four of the twelve inoculated were clean. It is true that some late infection had occurred on uninoculated fruit, but not nearly so generally as on the inoculated fruit. On the Baldwins some spots appeared, but the success of the inoculations was not so great as on the Rhode Island Greenings. These experiments were duplicated later with negative results.

Method of infection

In connection with the writer's infection experiments an attempt was made to determine how the germ tube pierces the cuticle of the host. Inoculated leaves were gathered at various dates. Some were put up in fixer and embedded in paraffin. Others were cooked for a short time in caustic potash, after which the epidermis could be peeled off and mounted on a slide. This being done, it was easy to locate some of the germinating spores and to trace the course of their germ tubes through the cuticle and for some distance between the cuticle and the epidermis. In Fig. 185 is shown a camera lucida drawing of an early stage of infection by an ascospore. In general it seems that the germ tube bores directly through the cuticle and continues to grow between the cuticle and the epidermis.

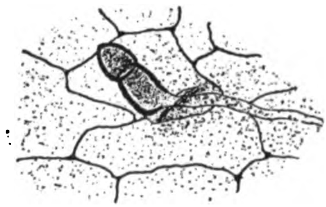


FIG. 185.—*Ascospore infection, showing the germ tube from an ascospore entering between the cuticle and the epidermis. Camera lucida drawing*

As noted above, Aderhold observed a slight broadening of the germ tube at the point of entrance, and the formation of appressoria. This did not occur in any of the cases observed by the writer. Fischer (1909) states that the fungus cannot enter an entirely sound fruit without a break in the epidermis. He believes that changes of temperature, by expanding or contracting the tissues of the fruit, may separate the cuticle from the epidermis, permitting the growth of the fungus in such places. The writer cannot see that there is much ground for this opinion. It seems that a germ tube from a spore is able to attack a perfectly sound fruit, although one cannot be sure that certain injuries which are not detectable might not be present.

Aderhold (1900) records experiments which lead him to believe that in the case of *Venturia pirina* the pectic compounds between the cuticle and the epidermal cells exert a chemotropic influence on the germ tube of the fungus and probably also supply nourishment.

(1900) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 29: 562–565.
(1909) Fischer, F. Über die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 19: 432–434.

Time of infection

From data recorded in Table 2 it seems evident that the first appearance of scab on leaves in 1908 and in 1910, undoubtedly due to ascospore infection as will be shown later, was directly traceable to certain rains which furnished conditions for infection; and that the dates of these rains are the dates of infection, thus giving approximately the period of incubation in each case.

Artificial inoculations recorded above show that the period of incubation may vary from eight to fifteen days. In the table, therefore, all rains are recorded which occurred within these time limits previous to the date on which scab appeared; and the limits are further broadened so as to include all rains occurring five to eighteen days previous to the appearance of the disease, in order to allow for any possible greater variations that may have occurred.

TABLE 2. DATES AND AMOUNT OF PRECIPITATION PREVIOUS TO THE FIRST APPEARANCE OF SCAB ON LEAVES DUE TO ASCOSPORE INFECTION, INCLUDING ALL CASES OF RAINFALL THAT COULD BE RESPONSIBLE FOR EACH INFECTION. THE DATES ON WHICH INFECTION PROBABLY OCCURRED ARE SET IN BLACK-FACE TYPE

1908 (first appearance on May 22)			1910 (first appearance on May 12)		
Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared	Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared
May 16	.15	6	May 2 to 3	.75	9 to 10
May 15	.12	7	May 1	.25	11
May 14	.30	8	April 29	.25	13
May 13	.12	9	April 26	.25	16
May 11	.01	11	April 25		17
May 10	.03	12	April 24	1.25	18
May 9	.36	13	April 23		19
May 8	.33	14			
May 7	.40	15			
May 6	.08	16			

In 1908 the first infection appeared on May 22. As the mature ascospores were found on May 4 it is safe to assume that some infection occurred during the rains of May 7, May 8, and May 9, since these furnished the first favorable conditions for infection after the spores had matured. This gives an incubation period of thirteen to fifteen days. Conditions favorable for infection also prevailed on May 13 and May 14, in which case the period of incubation would be eight to nine days; this period corresponds

with inoculation experiments made early in the season. Since the spores were mature at the date of the earlier rains (on May 7 to May 9), there is no reason to believe that the infection did not occur at that time. Infections that appeared later probably occurred during the later rains (on May 13 and May 14). It is evident, therefore, that the infection appearing on May 22 occurred during one of the two rainy periods recorded above, probably the earlier period (May 7 to May 9).

In 1910, at Sodus, ascospores began to ripen about May 1. On April 29 and May 1 some rain fell; on May 2 and May 3 the precipitation was .75 inch, with good conditions for scab infection. The infection appeared on the leaves on May 12, giving a possible incubation period of nine to thirteen days. The table shows that there were weather conditions which would permit infection earlier than this date, but the following reasons exist for the opinion that there was no infection prior to April 29 and probably none before May 1: first, the ascospores were just beginning to ripen on May 1; and, second, spray applied on April 29 preserved the foliage from infection.

The abundant appearance of scab from secondary, or conidial, infection is shown in Table 3, which is constructed on the same plan as is Table 2:

TABLE 3. DATES AND AMOUNT OF PRECIPITATION PREVIOUS TO ABUNDANT APPEARANCE OF SCAB ON LEAVES DUE TO SECONDARY (CONIDIAL) INFECTION, INCLUDING ALL CASES OF RAINFALL THAT COULD BE RESPONSIBLE FOR EACH INFECTION

1908 (abundant appearance at Ithaca on June 28)			1910 (abundant appearance at Sodus on June 7)		
Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared	Date of rainfall	Amount of precipitation (inches)	Number of days before infection appeared
June 15	.46	13	May 25	.54	13
June 14	T*	14	May 24		14
June 10	.01	18	May 22	.15	16
June 9	.13	19	May 20	.19	18
June 1	.01	27	May 18	.11	20
May 31	.41	28	May 10	.08	28
May 30	.16	29	May 9	.08	29
May 29	.05	30	May 8		30

*Trace; an amount less than .01 inch, too small to be measured.

In 1908, at Ithaca, abundant secondary infection appeared on June 28. In this case there is little doubt that the infection occurred on June 15, when .46 inch of rain fell. This gives a period of thirteen days for incu-

bation. It is certain that the period of incubation was not less than thirteen days, since, excepting a trace on June 19, no more rain occurred until June 23, only five days previous to the appearance of lesions.

In 1910, at Sodus, the first production of conidia from which secondary infection could be expected appeared on May 12, as shown in Table 2. The first rainfall after this time occurred on May 18, with showers in the night and in the forenoon. Since these rains, however, consisted of intermittent showers, it is probable that the foliage did not remain wet long enough at one time to permit abundant infection to occur. It seems much more probable that the abundant appearance of scab on June 7 was the result of infections that occurred during the rain of May 24 and 25, when conditions were much more favorable for such an infection. In the latter case rain began to fall gently and steadily at 4 p. m. on May 24, with heavy rain during the following night, followed by a cloudy forenoon on May 25 with drizzling, or misting, showers, and a cloudy afternoon. Since this rain furnished the first really good infection weather after the conidia appeared — May 12 — and since abundant infection became evident on June 7, it may be concluded that the incubation period in this case was of thirteen to fourteen days duration.

In studying these tables, it must be borne in mind that the amount of precipitation is not necessarily the important factor in determining whether or not a certain rain permits infection. A more important factor is the length of time that the trees remain wet so as to allow spore germination (Plates IX and X). In fact it is theoretically to be expected that a heavy, beating rain would be less favorable to infection by the fungus, since constant washing would have a tendency either to keep many of the spores moving from place to place — not allowing sufficient time in any one position for them to become established in the tissues of the host — or to wash many of them to the ground. The ideal condition for infection is a gentle, continued rain followed by cloudy, calm weather and a saturated atmosphere, in which case the spores are kept wet for a long time while in one position.

Ascospores have been observed to germinate within a period of four hours, but it is probable that in order to produce abundant infection the trees must be kept wet for eight or ten hours or even longer. Any condition tending to favor the retention of moisture after rain has ceased tends to favor infection by the fungus. Several factors may be mentioned in this connection: dense foliage prevents prompt drying-out of the trees after rain has ceased; good air drainage favors rapid drying of trees, for which reason orchards located on hilltops are, in general, less likely to be seriously attacked by scab than are those in sheltered locations where there is poor circulation of air; showers occurring during the day, followed

by winds or other drying conditions, are not likely to permit infection; showers occurring in the evening, followed by a calm night with a humid atmosphere, are likely to allow abundant infection. Conditions were favorable for infection on each of the dates mentioned above.

In Table 4 is shown the relation of the development of fruit buds and the maturity of ascospores to early scab infection. The data on infection are the same as those recorded in Table 2.

TABLE 4. CORRELATION OF THE FIRST APPEARANCE OF SCAB DUE TO PRIMARY INFECTION AND THE DATE ON WHICH THIS INFECTION PROBABLY OCCURRED, WITH THE DEVELOPMENT OF ASCOSPORES AND OF FRUIT BUDS

Year	Date of first appearance of scab	Condition of buds at date of first appearance of scab	Probable date of infection, as shown in Table 2	Condition of buds at probable date of infection	Date when mature ascospores were first found
1908	May 22......	Petals falling	May 7 to 9...	Almost opening	May 4
1910	May 12.....	Mostly in bloom	May 2 to 3...	Ready to open	May 1

From Table 4 it appears that in 1908 the first infection on leaves and pedicels of crab-apple appeared as the petals were falling, on May 22. As is shown in Table 2 the period of incubation was evidently thirteen to fifteen days, making the dates of infection May 7, May 8, and May 9. This was several days before the blossoms opened. Ascospores were found to be mature on May 4, which would provide the necessary source of infection at the time when the rains referred to in Table 2 (on May 7 and May 9) occurred.

In 1910, on apple leaves at Sodus, it is evident that the early infection occurred just as the blossoms were ready to open (Plate XI), that is, on May 2 to May 3. In this case mature ascospores were first found on May 1.

From the above data it appears that the leaves and buds of the apple are susceptible to infection as soon as they are exposed, but that infection does not occur until the ascospores have matured or until the first appearance of weather conditions favorable for infection following the maturity of ascospores. According to observations during the past three years, the spores do not reach maturity until the blossoms are either opening or just ready to open. It seems, therefore, that there is little danger of abundant infection earlier than about the time when the blossom buds show pink.

Place of primary infection

The reason for blossom-bud leaves' becoming scabby earlier than others is another point relating to this early infection that is worthy of consideration. Many investigators have noticed that the leaves of blossom buds become scabbed earlier, and are often found to be infected worse, than those from leaf buds; others, who have not noticed this, have noted that flower-bud leaves are more easily burned by a spray mixture. This greater susceptibility to injury in many cases is the result of previous scab infection. These leaves are the first to open in spring; they are exposed to the earliest infection, while those from the leaf buds do not appear until later (ten days) and thus escape it. The leaves from fruit buds are exposed to both ascospore and secondary conidial infection, while those from leaf buds are, for the most part, subject only to the secondary attack.

In Table 5 is shown the same relation of the development of fruit buds and conidia to the secondary, or conidial, infection as appears in Table 4 to the primary, or ascospore, infection:

TABLE 5. CORRELATION OF THE FIRST ABUNDANT APPEARANCE OF SCAB DUE TO SECONDARY (CONIDIAL) INFECTION AND THE DATE ON WHICH THIS INFECTION PROBABLY OCCURRED, WITH THE DEVELOPMENT OF THE FIRST CROP OF CONIDIA AND OF FRUIT BUDS

Year	Date when secondary infection first appeared abundantly	Condition of buds at date of appearance of secondary infection	Probable date of infection, as shown in Table 3	Condition of buds at probable date of infection	Date when conidia from primary infection (source of secondary infection) appeared, as shown in Table 2
1908	June 28......	Apples ¾ to 1 inch in diameter	June 15......	Apples about ½ inch in diameter	May 22
1910	June 7......	Apples ½ inch in diameter	May 24 to 25	Petals falling	May 12

As intimated above, the ascospore infection is often not severe in itself. It is the original source, however, of this conidial infection, which is often much more abundant and which usually causes most of the scabby fruit as well as the most abundant leaf infection.

In Table 5 it appears that abundant leaf infection at Ithaca in 1908 appeared on June 28, when the young apples were about three fourths inch in diameter. In Table 3 it is shown that the infection probably occurred

on June 15, thirteen days previous. On June 15 the young fruit was about one half inch in diameter. In 1910, at Sodus, secondary infection appeared on June 7, when the apples were about one half inch in diameter. In Table 3 it is shown that the infection in this case probably occurred on May 24 to 25, thirteen to fourteen days previous to the date of its appearance. At this time the trees were in full bloom and some blossoms were falling.

The writer has no satisfactory explanation to offer as to why the abundant secondary infection did not appear earlier in 1908, since the first crop of conidia, as shown in Table 2, was produced as early as May 22* while the infection did not take place abundantly until June 15. Weather conditions apparently favorable for infection occurred at intervals between May 26 and 31. It is probable, then, that some infection did occur at this time, but it is apparent that the abundant infection constituted the third generation of the season. In 1910, as shown in Table 3, this abundant infection occurred much earlier, evidently during the first continuously rainy period following the appearance of the first crop of conidia. In this case, then, the infection unquestionably represented the second generation of the season.

Another method of determining the date of infection and the period of incubation was attempted to a limited extent during the spring of 1908. On May 16 certain branches were inclosed tightly in paper sacks. The sacks were removed on May 26 and the leaves were found to be as badly scabbed as uncovered leaves, showing that this infection, which had already been visible about two days, had taken place previous to May 16, thus making the period of incubation more than eight days. Some of the sacks were not removed until later, and these prevented abundant secondary infection which appeared on the unbagged branches about June 28.

Clinton (1901) observed in 1898 that scab first appeared about May 2, at which time the oldest leaves had not reached full size. In 1899 the disease appeared first on May 5, a few days later than in the previous year. Clinton notes that the later leaves were the most infected in the latter year, while the earlier ones from flower buds were the most infected in 1898. The Venturia stage was later in developing in 1899. Clinton gives no data in either case. In 1900 scab was first found on May 11 and did not make a general appearance until the latter part of the month. Clinton observed further that in 1898 scab appeared more abundantly on the under surface of the leaf because this surface is exposed earlier than the upper surface. In 1899, when the infection occurred later, the leaves were mostly affected on the upper side.

* Conidia were present as soon as infection appeared.

(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:114.

As an explanation of the more abundant infection of leaves from flower buds in 1898, Clinton suggests that infection is carried by insects and also that these leaves are probably the most affected because they are the first exposed. The same phenomenon was observed by the writer in 1909 and 1910. It was especially marked in 1910. The writer believes that the latter explanation is the more probable one. It is evident that this infection has occurred in some cases before the blossoms opened, as shown in Table 4, and therefore before insects are likely to visit the blossoms in very great numbers. While it is not to be doubted that insects may carry spores, the writer is of the opinion that scab infection results oftener from wind-blown or rain-washed spores.

The development of the two forms of this fungus as outlined by Clinton (1901) agrees in general with the writer's observations as recorded in the text. The following paragraphs are quoted from Clinton's bulletin:

May. Scab first appears on young apple leaves and fruit and during this month and June obtains its greatest foothold.

July to September. The warm, generally dry, weather is not very favorable for spreading the disease to the leaves, and fruit usually suffers but little from further infection.

September and October. Scab appears to develop somewhat more abundantly especially on the lower surfaces of the leaves, but not necessarily in vigorous fruiting condition.

October and later. On the fallen dead leaves there are signs of the formation of the perithecia of the Venturia stage.

October to April. Perithecia slowly develop as weather conditions prove favorable.

April and May. Perithecia with mature ascospores are now found.

June. Venturia stage disappears.

Late infection and scab development in storage

While the cycle indicated above may be regarded as the usual one, it is to be noted that seasonal variations markedly influence the development of the disease. In the case of abundant fall rains accompanied by fog, or the occurrence of excessive dew, a late infection of scab appears. The disease may not appear on infected fruit until the fruit is stored. This phenomenon has been called to the writer's attention recently by several investigators and growers. It is not new, however, for Goethe (1889) noted that scab developed in certain cases and new infections occurred after the fruit had been stored.

Brooks (1908) reports a case of late infection on McIntosh apples. The fruit when picked was apparently free from scab. Two weeks later the apples from an unsprayed tree were found to be very scabby. Brooks states further that during the winter of 1907–1908 much trouble was experienced in the Boston cold-storage plants and many commission men lost heavily because of scab. He considers it unlikely that the disease

(1889) Goethe, R. Zur bekämpfung des apfelrostes. Gartenflora 38 : 241.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67:121.
(1908) Brooks, Charles. Notes on apple diseases. New Hampshire Agr. Exp. Sta. Rept. 19–20 : 372.

spread through the storage plant, and thinks it resulted either from minute colonies that were not noticeable at picking time or from spores lodged on the apples.*

The writer was informed by B. J. Case, of Sodus, New York, of a similar occurrence on Rhode Island Greenings. Mr. Case stated that a succession of very heavy dews occurred shortly before harvest time and that this doubtless furnished conditions for the infection. It is probable that heavy dews or very gentle rains would be more effective in inducing late fruit infection than would washing rains, which would tend to keep the spores in motion over the smooth surface of the apple. At the time of the early infection the surface of the young fruit is sufficiently rough and hairy to furnish lodging-places for the spores.

Such weather conditions, with some very gentle rains, occurred during the fall of 1910 and considerable late infection was noted in some cases. This had appeared to a somewhat limited extent on the Rhode Island Greenings in the writer's experimental plats at Sodus which had not received the late application of spray. The percentage of scab on these plats was 17, as compared with 12 per cent on plats similarly treated but receiving a later application of a fungicide. The inoculation experiments reported earlier in this bulletin also indicated the possibility of this late infection and the time when it may occur.

Morse (1910) reports a very serious occurrence of late infection in Maine. During the winter of 1907–1908 hundreds of barrels of Maine apples, which were free from scab when placed in storage, were later found to be thoroughly covered with small black specks. Morse states that the entire growing and harvesting season was very wet and that the vegetative development of the fungus continued up to harvest time. Then the moist apples, covered with spores, were placed in rather warm cellars, resulting in the infection of the fruit and the formation of small scab spots on the apples in storage.

Morse and Lewis (1911) note an instance which would seem to indicate that scab infection has actually occurred in storage. It was found that apples lying adjacent to those that were scabby when placed in storage became infected. Morse notes also that Professor F. C. Sears, of the Massachusetts Agricultural College, has informed him that the development of scab on stored apples is not uncommon in Nova Scotia.

McAlpine (1904) reports late scab infection in Australian orchards. The disease is said to have appeared in December and January on apples

* Brooks gives no evidence that infection may not have taken place before the apples were gathered. That the fruit may have been gathered during the period of incubation is perhaps in most cases the explanation, rather than that infection occurs after harvesting.

(1904) McAlpine, D. Black spot of the apple. Victoria Agr. Dept. Bul. 17 : 6.
(1910) Morse, W. J. Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164 : 4.
(1911) Morse, W. J., and Lewis, C. E. Maine apple diseases. Maine Agr. Exp. Sta. Bul. 185 : 352–355, 390.

that had previously been fairly clean. This occurrence McAlpine attributes to unusually wet weather.

How the fungus passes the winter

Several possibilities have been suggested in answer to this question. One suggestion is that conidia which may lodge on the twigs or about the bud scales are able to retain their vitality and to germinate when favorable conditions arise in spring. Another suggestion is that the stroma of the fungus on twigs, or even on decayed leaves or fruit, may withstand the winter and produce in spring a new crop of conidia to start the infection.

Vitality of conidia.—Aderhold (1896) reports that, although the conidia of *Venturia inæqualis* germinate very readily and quickly, they soon lose their power of germination. Spores kept for eight weeks between glazed paper would not grow on gelatin. On the other hand, Aderhold notes that certain hyphal threads from cultures that had apparently been dormant for three months could awaken to renewed life when placed under favorable conditions. Further, he adds that it is not unusual to find the old hyphal cells rounded off, and these in suitable media produce mycelium by means of hyphal threads. Aërial threads may also be used in producing new cultures, and in the same way bits of stroma from old spots are agents of reproduction.

Ewert (1910) conducted experiments in order to determine the ability of conidia of various fungi to withstand low temperatures. Among these, conidia from the pear-scab and the apple-scab fungus, taken from diseased leaves and fruits, were tested. They were subjected to three periods of freezing, each of six hours duration at a temperature of 16° to 5° C. The freezing did not at all reduce the viability of the conidia of *Venturia pirina*, while only an occasional spore of *V. inæqualis* germinated after the second freezing. It would seem from these experiments that the conidia of *V. inæqualis* would probably be unable to survive the winter frost.

Hibernation of conidia.— McAlpine (1902) thought that the only source of infection worth taking into account, so far as Victoria (Australia) is concerned, is from the spores produced on the leaves or the fruit in one season, which may become entangled in the hairs or scales of the buds and may germinate when favorable conditions occur in the following spring. At that time McAlpine had not found in Australia any trace of the perithecial stage of the fungus. It is not probable that he would adhere to this view at present.

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25 : 892.
(1902) McAlpine, D. The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. 1 : 707.
(1910) Ewert, Dr. Die überwinterung von sommerkonidien pathogener ascomyceten und die widerstandsfähigkeit derselben gegen kälte. Zeitsch. pflanzenkr. 20₁: 138–139.

Lawrence (1904) reports having found the scab fungus on the apexes of a number of fruiting spurs of both Baldwin and Rhode Island Greening trees. These spurs were noted in the following spring and a fungus was found which produced spores much like the conidia of Venturia. Lawrence remarks: " If these were summer spores of the scab fungus they are produced in such small numbers, and mature at such a time, that they will be killed by the spraying recommended below."

Lawrence believes that he found conidiophores in spring on old, dead leaves. Those kept in moist chamber in a decoction of dead leaves for twenty days produced conidia on the new growth identical with those produced on small stalks from germinating winter spores. Lawrence thinks there is little question but that these are true forms of the scab fungus. In examining many thousands of infected leaves in New York State, the writer has never been able to observe conidia produced on old, dead leaves in spring.

Persistence of stroma on twigs.—Apple scab has been observed by Stewart and Blodgett (1899) to occur on the twigs of Lady apples, which they report as being a variety very susceptible to this form of attack. Clinton (1901) notes having found scab on twigs but once, on a crab-apple tree. He regards the ascospores as the chief means of carrying the fungus over winter. He has since, however, reported to Professor H. H. Whetzel by letter that he has observed lesions frequently on twigs of Fall Pippin and certain other varieties of apples. Nevertheless he does not state that the fungus ever winters on the twigs.

According to Voges (1907 and 1910) it would seem that in some sections of Germany apple scab may grow abundantly on twigs; while in other sections it is at least very rare, since Aderhold, who has without doubt investigated the disease more carefully and thoroughly than has any other person, failed to find it on the twigs. Its occurrence must certainly have been very rare in the region where Aderhold conducted his investigations. However, Voges, as cited above, states that in his locality (in Hildesheim) scab was as common on apple twigs as on pear twigs. He names several varieties that have been badly affected in his garden, among which Ribston is mentioned.

The stroma of the scab spot on the twig, according to Voges, remains more or less dormant during the winter and produces a crop of conidia in spring. A section through such a spot, bearing conidia as found in March, is shown.

(1899) Stewart, F. C., and Blodgett, F. H. A fruit-disease survey of the Hudson valley in 1899. New York (Geneva) Agr. Exp. Sta. Bul. 167 : 283.
(1901) Clinton, G. P. Apple scab. Illinois Agr. Exp. Sta. Bul. 67 : 118.
(1904) Lawrence, W. H. The apple scab in western Washington. Washington Agr. Exp. Sta. Bul. 64 : 1–24.
(1907) Voges, Ernst. Ueber die schorfkrankheit der obstbäume. Deut. landw. presse 34 : 276–277.
(1910) Voges, Ernst. Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 20 : 385–393.

Salmon (1908) also reports finding scab on the young wood and shows photographs of infested twigs. In regard to the appearance of scab on young wood this author states: "According to the variety of apple attacked, its appearance varies considerably; in some cases e. g. on Coxe's Orange Pippin the diseased wood becomes somewhat swollen and prominently blistered. In other cases e. g. on Wellington the blistered appearance is less prominent, and the shoot is not swollen. In still other cases the scab produces isolated characteristic markings which give the wood a pocked appearance. Severely attacked young shoots may, as in the case of those of Lord Suffield, be blistered almost continuously over the surface, and the bark will then subsequently peal off in flakes." Salmon considers Coxe's Orange Pippin a susceptible variety.

The same author (1909) notes that twig infection was found to occur only on the following six varieties: Golden Noble, Ecklinville, Coxe's Orange Pippin, Blenheim Orange, Warner's King, and Peasgoods Nonesuch. It was very severe on Coxe's Orange Pippin and on Ecklinville.

Eriksson (1911) mentions having frequently observed the fungus on twigs of the current year's growth but not on older ones.

Considering all the evidence, the writer is convinced that the ascigerous stage is the principal agent involved in carrying the fungus over winter. It has been shown that twig infection is not of very common occurrence and that the conidia cannot withstand winter temperatures. Furthermore, evidence that the ascospores are the chief source of primary spring infection is furnished by the fact, noted more in detail in another part of the bulletin, that orchards the leaves of which have been plowed under or burned early in spring or late in fall are less seriously affected than are orchards in which the leaves are left exposed.

Formation of appressoria.— There might remain the possibility of infection resulting from the germination of appressoria produced by the mycelium, as described by Aderhold and already referred to. Since Aderhold describes these enlargements as becoming more or less brown in color, it may be possible that they are able to function as resting spores.

Summary

The observations on scab infection given above lead in general to certain conclusions with reference to the time and source of infection under conditions existing in New York State:

1. The early infection is chiefly, if not entirely, from ascospores, and it may appear during the first period of weather favorable to infection

(1908) Salmon, E. S. Apple scab or black spot. London Bd. Agr. Journ. 15 : 182–195.
(1909) Salmon, E. S. Black spot or apple scab. Southeastern Agr. Col. (Wye, Kent). Journ. 18 : 267–270.
(1911) Eriksson, J. Die rote farbe der fruchtschale und die schorfkrankheit der obstsorten. Zeitsch. pflanzenkr. 21 : 129–131.

occurring after the ascospores have matured. Usually this does not take place until blossoming time or immediately before. There seems to be little danger that infection will occur much earlier; this is probably not because the leaves and buds are not earlier susceptible to scab, but rather because the ascospores have not matured in sufficient quantities to cause general infection.

2. The period of incubation may vary from eight to fifteen days; so that after this length of time has elapsed subsequent to the date of the earliest ascospore infection a crop of conidia is produced, from which a second, and usually more abundant, infection may appear eight to fifteen days following the first period of weather favorable to infection that occurs after the above crop of spores has ripened. This generation may in turn produce another, and so on throughout the season. However, the various infections do not always occur only in successive jumps at intervals of eight to fifteen days, as the above discussion might lead one to believe. The crop of ascospores are not all matured and do not all discharge at one time. They begin to ripen at about the time indicated above and furnish a constant source of infection for a month or more. Thus the individual infections belonging to the first generation may be started at several different dates and consequently produce their first crops of conidia at different dates. It is possible also that individual infections occurring at the same time do not all have the same period of incubation. Thus there may be a more or less constant appearance of scab, with the more pronounced jumps at intervals as indicated above. In fact this is what usually occurs.

3. The earliest infections usually occur on the lower side of the leaves. This is due to the fact that the lower side is more exposed at that time, while the leaves are unfolding. The later infections occur more abundantly on the upper surfaces, which by that time have assumed a more exposed position.

VARIETAL SUSCEPTIBILITY

Perhaps the best method of obtaining data as to varietal susceptibility in case of this disease is to summarize the results that have been obtained and the observations that have been made by various investigators for years past. In reviewing this work it becomes evident that too much stress should not be laid on a single set of observations. It is found that certain varieties may be resistant in one year and susceptible in another year under conditions which for average varieties are as favorable to the disease in the one case as in the other. The experiments reported by Aderhold emphasize this point. The writer, on comparing his own results with those previously reported by others, finds the above statement to hold good.

Baldwin, for example, is usually listed among resistant varieties; yet on the check trees in the writer's experiments during 1910 Baldwin trees yielded ninety-eight per cent of scabby fruit, much of which was badly infected. In 1909, which was not an epidemic year, the Baldwins were as badly diseased as were the Rhode Island Greenings. The Ben Davis, which is usually reported as resistant, was as badly scabbed during both seasons as was the average variety.

It may be possible that the reputation of these varieties is due partly to their color. The scab is not so conspicuous on the dark-colored fruit as on that of the light-colored varieties. Many growers who had very scabby Baldwins in the season of 1910 considered them clean, while Rhode Island Greenings, which were really less diseased, were considered a scabby lot. However, as previously stated, it is possible that Baldwin and Ben Davis may be more or less resistant in some seasons, since it has been proved that such variations do occur.

There seems to be no satisfactory explanation for such variations, although several suggestions may be offered. They may be due to a relation of the weather conditions or of the time when weather favorable to infection occurs, to certain stages in the development of the fruit and the leaves of certain varieties. For example, a Baldwin may be just at its most susceptible stage at the time when weather favorable to infection occurs in this season, and in the next season may have passed this stage; while a Rhode Island Greening may so develop with respect to the weather as to give the opposite results each year. Therefore the Baldwin would be susceptible in one year in a certain locality, and the Rhode Island Greening in the next year. In some varieties the susceptible period may be reached sooner or may last longer than in other varieties; this explanation, however, is as yet only theoretical.

Another plausible explanation is suggested by a few statements made by Bailey (1892), from whom the following is quoted:

> One other important consideration must not be overlooked here, and that is the fact that enemies often progress or develop as rapidly as do the host plants. I imagine that by the time we are able to breed scab-proof varieties — from the present standpoint — our scab-fungus will have developed a capability to attack more uncongenial hosts. This is the common history of injurious insects and fungi; they take on new habits to accommodate themselves to new conditions. It is possible that a good market apple may spring up which is for the time scab-proof; but when we have learned how to produce such kinds with tolerable certainty, the enemy will have grown cunning too, I fear. How many are the pears which are sent out as blight-proof, and yet in a few years they suffer with the rest. We are in the habit of distrusting the originator who makes this claim if it turns out false in after years, but I am inclined to think that some of these varieties really are measurably blight-proof at first. If the histories of varieties of fruits could be written from the natural-history side, I fancy that many of our notions would be upset.
>
> I would not discourage Doctor Hoskins' efforts toward scab-proof apples, but I am not over-confident of success. For my generation, at least, I must pin my faith to the squirt-gun.

(1892) Bailey, L. H. Scab-proof apples. Garden and forest 5 : 442.

The above was written in connection with a discussion of the Baldwin apple. At that time this variety was considered fairly resistant to scab, yet Professor Bailey notes that in some cases it was attacked to some extent. It is significant to mention here that during the season of 1910 the unsprayed Baldwins in Mr. Case's orchard at Sodus, New York — one of the most carefully-cared-for orchards in the State — gave ninety-eight per cent of scabby fruit. Might it not be possible that the fungus has become better adapted to this host than in former years, as predicted by Professor Bailey in 1892? It is not necessarily true that the scab fungus in general has become able to attack more uncongenial hosts; but in this particular Baldwin orchard a strain of the fungus that is capable of flourishing under favorable weather conditions on the Baldwin apple may have been bred merely by means of natural selection. It should be possible for experimenters to breed fungi as well as higher plants; and in a Baldwin orchard in which the fungus is more or less harbored for years, those strains that are capable of attacking that variety persist and multiply until finally the disease is as prevalent as in other orchards of other previously susceptible varieties.

There is no reason to expect that any variety on which the fungus can grow, no matter to how small an extent, will remain resistant indefinitely if it is permitted to select, cultivate, and multiply those strains of the fungus that are capable of attacking it. Perhaps if an absolutely immune variety could be found there would be hope that such a variety could be kept immune until some particularly virulent strain of the fungus lodged on it by chance. Then, if the virulent character of the latter is perpetuated, there is no reason why its offspring would not be multiplied, in time even producing an epidemic on this previously immune variety.

Voges (1910) claims that red-skinned varieties are much more resistant to scab than are closely related white varieties. He offers the suggestion that the coloring substance in the skin may in some way be the cause of the resistance to infection of such varieties. Eriksson (1911) takes issue with this view and cites cases in which red-skinned apples were as badly attacked as others.

Aderhold (1896) made a study of varietal susceptibility and, while great difference was noted, none of the four hundred and fifty varieties of apples cultivated in Germany were found to be immune. Aderhold concludes also, on comparing his obervations with those of Goethe, that varietal susceptibility may vary in different localities.

(1896) Aderhold, Rudolf. Die Fusicladien unserer obstbäume. Landw. jahrb. 25 : 894.
(1910) Voges, Ernst. Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 20 : 385–393.
(1911) Eriksson, J. Die rote farbe der fruchtschale und die schorfkrankheit der obstsorten. Zeitsch. pflanzenkr. 21 : 129–131.

The same author (1902) records the results of a five-years experiment on susceptibility of varieties and on the relation of weather to such susceptibility. One hundred and sixty-three varieties were kept under observation during the season from 1897 to 1901, inclusive. Notes were taken with reference to the disease on foliage. An elaborate tabulation was made showing the relative susceptibility of each variety in each season. Only a few varieties exhibited the same disease-resisting power throughout the five years, and almost without exception these were such varieties as suffered little during the great epidemic year of 1897. Some varieties, Aderhold notes, rose almost by bounds, so to speak, to a condition of relative freedom from disease; others were attacked very severely in 1900 and but slightly in 1901; while still others showed gradually less severe attacks each year. Aderhold notes further that not a few varieties which in 1897 — the epidemic year — were relatively immune, were very susceptible in 1898 and 1899. As a result of his investigations this author states that only those few varieties which were resistant every year can properly be considered resistant; and one can plainly see by examining his results that resistant varieties cannot be selected from the observations of a single season, even though that season be an epidemic one. This doubtless accounts for some of the conflicting reports on resistance of certain varieties to scab.

An anonymous author (1900) notes that certain varieties may appear to be immune in one season but may be very susceptible in another season, under different weather conditions. This author notes also that no variety can be considered entirely immune under all conditions. The same general sentiment is voiced by Fischer (1909), who states that no variety is immune and that many varieties may be practically free in certain seasons and yet suffer at other times.

CONTROL

SANITARY MEASURES

It should not be inferred from what has been said regarding infection by the perfect stage of the scab fungus that the disease can be controlled by sanitary measures alone. There will probably always be enough fallen leaves exposed to permit some infection, from which further spread may be rapid. It is doubtless true also that spores can be carried for considerable distances from neighboring orchards. If, however, the dead leaves are turned under, it is probable that much less danger will result from primary infection usually occurring about blossoming time. In most

(1900) Anonymous. Einige krankheiten und feinde der obstbäume und weinreben. Deut. landw. presse 27 : 721.
(1902) Aderhold, Rudolf. Ein beitrag zur frage der empfänglichkeit der apfelsorten für Fusicladium dendriticum (Wallr.) Fuckel und deren beziehungen zum wetter. Kaiserliches Gesundheitsamt. Biol. Abt. Land- u. Forstw. Arb. 2 : 560–566.
(1909) Fischer, F. Über die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 19 : 432–434.

cases the primary attack would probably be so light as to cause no serious results aside from furnishing convenient sources for more abundant secondary infection. Theoretically, then, it should be possible to dispose of many sources of primary infection by plowing the orchard in the previous autumn, or early in the spring before the ascospores have ripened.

A striking demonstration of this point was observed at Medina, New York, by the writer in 1909 and reported by Whetzel (1910). Several orchards in a certain locality were very severely attacked by the early infection. None of these orchards had been plowed and the leaves were found to contain perithecia in abundance. One orchard just across the road from one of those mentioned above had been plowed early in the spring and the old leaves were thus turned under. This orchard was comparatively free from scab on the leaves at the date when these observations were made.

Brooks (1909) also cites a striking demonstration of this point. He states: "The results were secured in two McIntosh orchards, which have been under observation for several years. Both have been seriously affected with scab each year, and the percentage of loss has been approximately the same in the two. Both orchards were in sod. About the middle of April a fire escaped from a sugar camp and swept over the entire area of one of these orchards. Not a scab spot could be found in this orchard the following summer, while the disease was quite common in the other orchard."

Other features of sanitation — such as the removal of rotted fruit and dead branches, and the like — although doubtless important in insect control, are probably not of importance so far as scab is concerned since the principal winter home of the fungus is in the leaves. Drainage, of course, should be considered a factor in case of very wet soils, since an excess of moisture favors development of the fungus by increasing atmospheric humidity; this hinders rapid drying of trees after rains and thus creates favorable conditions for the development of ascospores.

Pruning is an important factor. The denser the foliage of the tree, the more slowly it dries out after each rain. The longer the tree remains wet, the better is the opportunity for spores of the fungus to germinate and cause infection.

The location of the orchard with respect to air drainage is also important for the same reason. Trees situated on a hill, or otherwise located where there is free circulation of air, dry out much more quickly than do those growing in a pocket into which air currents commonly do not pass.

(1909) Brooks, Charles. Some apple diseases. New Hampshire Agr. Exp. Sta. Bul. 144 : 116.
(1910) Whetzel, H. H. Report of the committee on plant diseases. New York State Fruit Growers' Assn. Rept. 9 : 19–20.

SELECTION OF RESISTANT VARIETIES

This practice offers very little promise as a means of control. In the discussion of varietal susceptibility, it has been shown that no variety is likely to remain immune, or even very resistant, for many years. Further, even though a resistant variety could be obtained, the grower could not afford to sacrifice other desirable qualities for this one. Therefore it would seem better to select for quality of fruit and for productiveness, vigor, and hardiness of tree, and depend on some method of protecting the tree from scab.

SPRAYING

In view of the above discussion it will become evident that the most important method to be employed in controlling this disease is by timely applications of a protecting substance to the host. The early infection may be lessened by disposing of the dead leaves or by plowing them under. Proper pruning and good air drainage will aid in reducing danger of infection, and varieties may be selected that are somewhat less susceptible than others. But with all these precautions it is certain that clean fruit cannot be grown unless the trees are properly sprayed. This is now generally admitted and needs no argument. Much is yet to be learned, however, as to methods. The study of the habits of the parasite, which has already been dwelt upon in the text, is of importance chiefly as a means of learning how, when, and where it can be most effectively attacked without injury to the host plant.

The problem is to find the best fungicide and to learn how and, still more important, when it should be applied.

Fungicides

Some of the properties essential for a good protective fungicide may be enumerated as follows: first, the substance that goes into solution from the dried coating of spray material must have fungicidal value; second, this substance must go into solution in the presence of meteoric water, or it may be so brought into solution by the germinating spores of the fungus to be controlled, in sufficient quantity to prevent germination of the spores; third, it must not go into solution in such quantities or so rapidly that the material will all dissolve and be carried off with the first short rain, or in such quantities as to cause injury to the host if the resulting solution is caustic; fourth, the material, if applied as a solution, must change to a relatively insoluble form in drying on the plant, else the results will not be lasting as the substance will all be washed off with the first rain; and fifth, the material must adhere to the plant so that the solid particles will not be removed mechanically by rains or otherwise.

All these points must be considered in choosing a fungicide for the control of apple scab, as well as of other diseases of a similar nature when the principle involved is one of protection. There are many substances that are powerful antiseptics and have strong fungicidal properties but are not effective in controlling such diseases. Many such substances have been tested by reliable investigators and have proved to be inefficient.

McAlpine (1907) reports experiments in which were used certain proprietary sheep dips (Cooper's and Little's); also phenyl, phenylene, crude carbolic acid, and oil of tar, 1 part in 160 parts of water. None of these materials were at all effective in preventing scab.

There is no doubt that many of these substances possess fungicidal properties. Doubtless the reason why they do not succeed is that they are too easily soluble in water and do not change to an insoluble form after being applied. Since the fungicide protects from infection by forming a protective layer over the surface of the susceptible parts of the plant, there seems little reason to expect that a soluble preparation such as carbolic acid, which does not become relatively insoluble after drying on the plant, can be used in controlling such diseases as apple scab.

In the case of bordeaux, the mixture, of which copper is the essential fungicidal ingredient, is applied in the insoluble form and adheres to the plant like paint, forming a comparatively permanent protection. The copper is probably made effective by being very slowly brought into solution by means of certain agencies, either atmospheric conditions or the solvent action of spores, as needed. In the case of lime-sulfur solution, the sulfur, which is evidently the fungicidal ingredient, is applied in a soluble form. This would be almost, if not completely, washed off in the first few minutes of rain, leaving the plant unprotected even during the latter part of the same rain. During the drying process, however, certain chemical changes occur and the sulfur is deposited as a relatively insoluble precipitate, forming a protective and comparatively permanent layer as in the case of bordeaux mixture.

A third type of germicide, carbolic acid, may be compared with the two discussed above. This is applied in the soluble form. It dries on the plant without becoming insoluble; consequently it is dissolved and carried away in the first few minutes of rain and the plant is thereafter left unprotected. Carbolic acid may be a stronger germicide than lime-sulfur or bordeaux, but the lack of the one peculiar property, a proper balance of solubility, makes it worthless for this purpose.

Bordeaux mixture

Many fungicides and many combinations of fungicides have been tried in connection with the control of apple scab. Until very recently bordeaux

(1907) McAlpine, D. Experiments with black spot of apple. Victoria Agr. Dept. Journ. 5 : 362–363.

mixture has remained preeminently the standard, and the only spray used generally for the purpose. So much was this the case that the statement that bordeaux mixture is the best fungicide has become axiomatic. Most attempts at improvement in fungicides have been along the line of various modifications of bordeaux or by the use of other copper compounds. Many such combinations have been tried with varying success; the number of experiments of this kind is too great to permit of their mention here. Perhaps no one man has tried a greater number of such combinations than has McAlpine (1902), to some of whose very interesting experiments brief reference is here made.

In his report on control experiments in Australia during the season of 1901 and 1902 McAlpine records the use of many modifications of bordeaux mixture, with some suggestive results. Many substances were used, such as linseed oil, sal ammoniac, nitric acid, alum and salt, molasses, caustic soda, washing soda, permanganate of potash, bluestone, and rosin. In addition to these was a certain "Grant's mixture," with some unknown substance added. This gave much better control in every one of the three sets of experiments than did ordinary bordeaux or any other modifications tried. The addition of common salt seemed to increase somewhat the efficiency of bordeaux.

Dust sprays

Dust sprays, if efficient, can be applied with much less expense than other sprays, and can be used in orchards so located topographically that it is difficult to transport heavy spraying apparatus. In most cases in which comparative tests of dry spray and liquid spray have been made, a dry bordeaux preparation was used, which was applied with a special blowing apparatus.

The results in general have been decidedly discouraging for the dust spray, as will be shown by the following reports. In many cases the dust spray seemed to have no effect whatever in controlling the fungus, and in other cases but little effect. In one State, however, the dust spray seemed to give fairly good results in controlling scab.

Close (1905 and 1906) compared dust sprays with liquid sprays for the control of apple scab and other pests. The dust spray controlled apple scab very well in both seasons. The author concludes that the dust spray promises well for Delaware. No further experiments have been reported by him.

A series of experiments covering a period of three years, comparing

(1902) McAlpine, D. Experiments in the treatment of black spot of the apple and pear. Victoria Agr. Dept. Journ. 1:620–630.
(1905) Close, C. P. Dust spraying in Delaware. Delaware Agr. Exp. Sta. Bul. 69 : 1–7.
(1906) Close, C. P. Third report on dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 76 : 1–19.

dust sprays with liquid sprays, was conducted by Crandall (1906) of Illinois. In these experiments a dry bordeaux was used in combination with paris green. The test was repeated in each of the seasons 1903, 1904, and 1905. In every case the dust spray is reported as almost worthless so far as controlling apple scab is concerned. Even the foliage was not protected and it fell from the treated trees about as badly as from those untreated.

Faurot (1908) reports experiments in Missouri, where the use of home-made and commercial dust bordeaux resulted in only four to five per cent of scab-free fruit while the use of liquid bordeaux resulted in over ninety per cent.

Lawrence (1906) obtained eighty-eight to ninety-seven per cent of scab-free fruit with liquid bordeaux and only one to nine per cent with dust bordeaux. In another experiment reported by Lawrence, liquid bordeaux protected eighty-four to ninety-three per cent of the fruit and dust bordeaux protected only five to eight per cent.

The examples given are sufficient to indicate that under ordinary conditions little or no dependence can be placed on a bordeaux dust spray such as has been used up to the present time. These examples do not preclude the possibility of finding a satisfactory dry preparation, however, and if some form of dust spray can be devised that will be efficient the cost of spraying will be much reduced.

Lime-sulfur preparations

Lime-sulfur solution.— The use of lime-sulfur preparations as fungicides is discussed in detail by the writer in three bulletins recently published by the New York State College of Agriculture at Cornell University: Bulletin 288, Spray injury induced by lime-sulfur preparations; Bulletin 289, Lime-sulfur as a summer spray; Bulletin 290, Studies of the fungicidal value of lime-sulfur preparations. It is therefore not necessary to repeat that discussion here, further than to say that the work on this problem begun by Cordley (1908) — to whom belongs the credit of introducing on a practical basis in America the use of lime-sulfur solution as a summer spray — has progressed with increasing momentum each year since its beginning. The result is that to-day a large number of growers throughout the country have profited by the experience of the several investigators who have been working on the problem, and are using lime-sulfur solution combined with lead arsenate as a summer spray for apples.

(1906) Crandall, C. S. Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106 : 205–242.
(1906) Lawrence, W. H. Apple scab in eastern Washington. Washington Agr. Exp. Sta. Bul. 75: 1–14.
(1908) Cordley, A. B. The lime-sulphur spray as a preventive of apple scab. Rural New-Yorker 67 : 202.
(1908) Faurot, F. W. Spraying versus dusting. Missouri Fruit Sta. Bul. 19 : 1–24.

The principal advantage of lime-sulfur over bordeaux mixture lies in the fact that the severe russeting of fruit often resulting under certain weather conditions from the use of the latter is avoided. The fruit sprayed with lime-sulfur usually has a much smoother, more highly colored skin and a more waxy finish than has that sprayed with bordeaux mixture. The occurrence of bordeaux injury has seemed to be more common within recent years than formerly, and the advent of an efficient substitute which promises to avoid the difficulty has been heartily welcomed by growers.

It must not be understood, however, that the use of lime-sulfur with lead arsenate is advised as the only summer spray for apples. This recommendation at present is safe for New York State, since here scab is the all-important fungous disease for which spraying must be done. Farther south, however, bitter rot and apple blotch are of vital importance, and Quaintance and Scott (1912) have determined that lime-sulfur solution cannot be relied on to control those diseases. Where they are present the lime-sulfur treatment for scab should be followed by later applications of bordeaux mixture.

Scott lime-sulfur.— In addition to the lime-sulfur solution which consists essentially of basic calcium sulfids, prepared by boiling together in water lime and sulfur in proper proportions and properly diluted, there has arisen the self-boiled lime-sulfur devised by Scott (1909) and used by him so successfully for the control of peach rot and peach scab. This, although highly effective for those diseases, seems rather inefficient for the control of apple scab, probably largely because it does not adhere so well as is desirable.

Waite's modification.— An interesting set of experiments is reported by Waite (1910) on results obtained by the use of several modifications of self-boiled lime-sulfur and bordeaux mixture. The most promising of these was prepared by adding iron sulfate to self-boiled lime-sulfur mixture. This seemed to increase the efficiency of the latter, which at the same time retained its freedom from injurious properties.

When to spray

First application

The fundamental principle on which this phase of the subject is based has already been discussed in connection with the study of infection. To know when infection occurs is to know when to spray. As has already been pointed out, the fungicide must be applied before the infection occurs

(1909) Scott, W. M. Lime-sulfur mixtures for the summer spraying of orchards. U. S. Agr. Dept., Plant Indus. Bur. Circ. 27 : 15–17.
(1910) Waite, M. B. Experiments on the apple with some new and little-known fungicides. U. S. Agr. Dept., Plant Indus. Bur. Circ. 58 : 1–19.
(1912) Quaintance, A. L., and Scott, W. M. The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Agr. Dept. Farmers bul. 492 : 23–26.

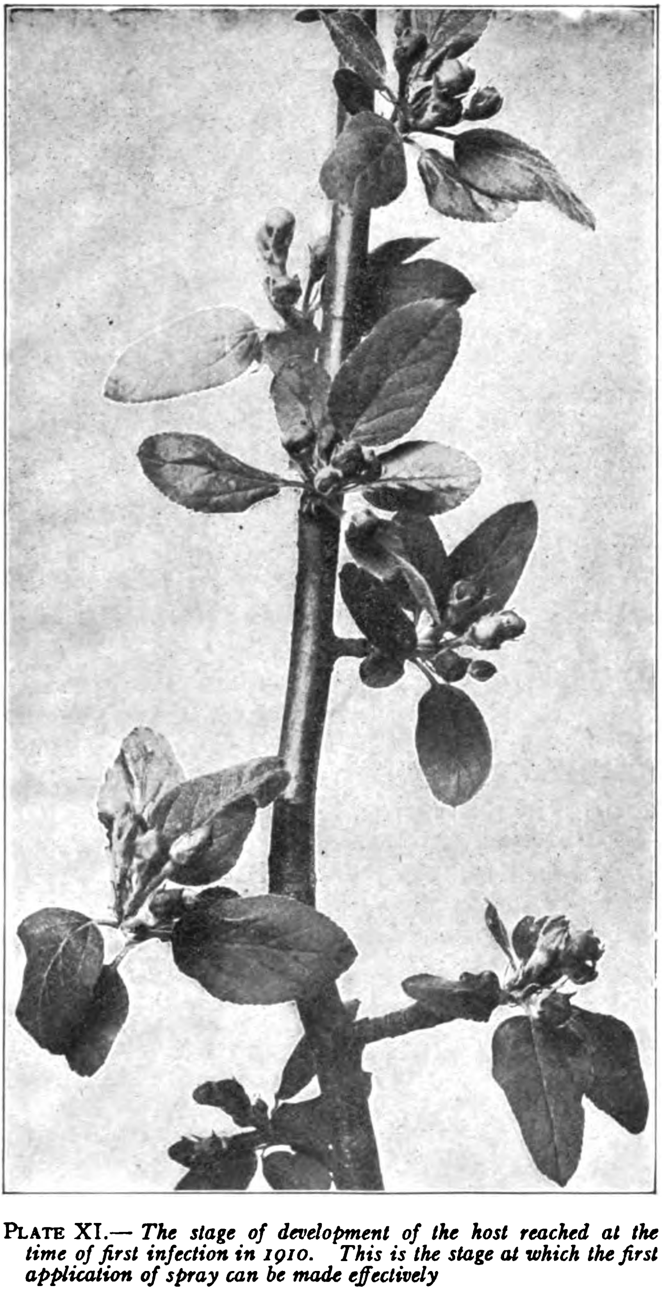


PLATE XI.— *The stage of development of the host reached at the time of first infection in 1910. This is the stage at which the first application of spray can be made effectively*

in order to prevent it. The first infection usually occurs when the blossoms are about to open, or as soon thereafter as favorable weather conditions arise. Spraying for scab must be begun before this time if the trees are to be insured against early infection. Since the ascospores do not mature until about the time when the blossom buds show pink, the first application may be delayed until about that time. Spraying experiments in 1910 added evidence to this conclusion. Although the weather from the time when the leaf buds first opened was such as to furnish ideal conditions for fungous infection, the spray applied after the buds were showing considerable pink prevented the early infection.

The primary infection is often very light. In many cases it is not sufficient in itself to cause much loss. This accounts for the fact that in many cases the application before the blossoms open has been omitted without loss. Several factors may enter into the conditions governing this point. An abundance of dead leaves lying open under the trees, and the development of an abundance of perithecia in these leaves. furnish the source of infection, and wet weather at the right time furnishes the conditions.

Later applications

An application after the blossoms fall is necessary in order to protect the trees from later attacks, and it is also advisable, under ordinary conditions, to spray again two or three weeks later. By this time the apples will have grown considerably and new surfaces will have been exposed. Sometimes a fourth application in late July or in August is necessary in order to prevent late infection.

Not only should the grower watch the conditions of the fruit buds, but he should also watch the weather and attempt to get the spray on ahead of general storm periods if possible. Many growers delay the spraying until after the rain is over if rainy weather happens to be threatening at the time, thinking that the rain will wash off the spray. No worse mistake than this can be made. It is during wet weather that the spray is needed to protect the trees from infection, which occurs only in the presence of excessive moisture. The spray does not wash off so easily as is ordinarily supposed. If it has twenty-five minutes in which to dry before any washing rain occurs it will adhere well. Any spray that will not stand some washing after it has once dried on the tree cannot be considered an efficient preventive for this disease.

Dormant spraying

There appears to be an opinion prevalent that winter spraying is important in connection with the control of apple scab. Several persons

have advocated the substitution of the dormant spray for the application just before the blossoms open.

The life history of the fungus in its relation to this point has already been discussed. Evidence presented in that discussion shows that the main source of early infection is the dead leaves. Spraying the trees before the leaves open cannot be expected to protect from this source of infection, because the leaves and the young buds which are to be protected are not yet exposed so that the spray can reach them.

It has been suggested that the conidia can live over winter on the twigs or the bud scales and that the spray applied during the dormant period kills them. It has been shown, however, that the conidia are not likely to live through the winter, and further that apple scab, unlike pear scab, is not of common occurrence on the twigs.

Even though it be admitted that some infection from either of the above sources may occur, it would not change the facts from the practical standpoint. It is known certainly that ascospores are responsible for at least most of the early spring infection, and that it is necessary to spray in order to protect trees from this source. It is further known that it is impossible to protect trees from this source except by coating the surface of the parts to be protected with the spray, and this cannot be done until those parts are exposed.

Spraying fallen leaves

The question is sometimes asked, will the spray falling on the dead leaves beneath the tree kill the ascospores or prevent them from being discharged? A study of the mechanism by means of which the spores are discharged will answer this question. The spores, being borne in a closed perithecium as shown in Fig. 183 (page 555), are protected from the fungicide until their discharge takes place. It will be seen further, from the same figure, that the asci containing the spores protrude beyond the surface of the leaf, passing the spores safely through any coating of spray material that may be present without even necessitating their contact with it.

Summary

Thus far mainly the theoretical side of the question as to the time of spraying has been presented. If the facts show that winter spraying can be depended on to control, or even to prevent, early infection the theory must be wrong. Some persons have considered that the amount of scab is decreased by a winter spray; but that the winter spray cannot be depended on to replace any of the summer applications seems clear. During the seasons of 1909 and 1910 certain trees were given this applica-

tion only, a strong lime-sulfur wash being used. In both these cases it was impossible to detect any difference in the amount of scab on sprayed trees and on unsprayed trees.

It is impossible to say what might happen in some cases, but it is certain that in the two cases mentioned above the dormant spray did not materially reduce the amount of scab. The methods that are most likely to be successful must be adopted. A method that has failed during two consecutive years is certainly not to be relied on. It should be understood that good results may be obtained for many seasons or under certain conditions when the application before the opening of the blossoms is omitted. In many cases a single spraying after the blossoms have fallen gives excellent results. The point to be emphasized is that in cases in which the early summer spraying is important, the dormant spray cannot be substituted for it.

Before leaving the discussion of the time for spraying, the writer wishes to emphasize the importance of making each application at the proper time and of being prepared to do so. Any grower having fifty to one hundred acres of mature apple orchard, who expects to do all his spraying with a single outfit, will find it absolutely impossible to comply with the above requirements, since, as can be seen, the time limit for the most effective application of each spraying usually does not exceed four or five days. The rule for every grower, therefore, should be to provide sufficient spraying equipment to thoroughly spray his entire orchard within four or five days at the most. This is much more important than is generally supposed, since the spray may entirely fail to control scab if delayed one or two days too long, thus permitting the infection to occur before the application is made.

Effect of continued spraying

While, as has already been pointed out, spray applied to even the badly diseased orchards during the first year may be expected to result in clean fruit it is doubtless true that continued spraying year after year has a cumulative effect on the vigor of the trees and thus enables them to set a larger crop of fruit than they could if left unsprayed. The foliage, being protected from the attacks of the fungus, remains healthy and vigorous; consequently the trees are able to produce a larger number of strong fruit buds than would otherwise be possible.

This point is already emphasized by experiments reported by Chester (1898) of Delaware. In experiments conducted with the same trees for three successive years, those unsprayed gave remarkably small yields

(1898) Chester, F. D. Report of the Mycologist. Experiment in the treatment of apple scab upon the farm of S. H. Derby, Woodside, 1897. Delaware Agr. Exp. Sta. Ann. rept. 10 : 39–45.

in the third year while the sprayed trees maintained the same quantity as well as quality of yield. In this connection Crandall (1906) notes that when the foliage of the season is lost as a result of severe scab infection, the trees are likely to attempt to repair the loss by pushing out leaves from buds that should remain dormant until spring in order to form the fruit crop of the next year.

There may be exceptions, however, to the above rule. If trees have over-borne in one season and consequently have not set fruit buds for the next season, it may happen that a severe early attack of scab, by thinning the fruit during the season of over-production, may enable the tree to set more fruit in the following season. An instance of interest in this connection, in the case of pears, is reported by Beach (1895). Eight Seckel trees that were sprayed six times in 1893 were compared with eight other trees of the same variety, under similar conditions except that they were not sprayed in 1893, as to production in 1894. Very little difference in yield was noted, and also very little difference in quality. The yield of the trees sprayed in 1893 was slightly greater, and the quality of the fruit was slightly better, than of those not sprayed in that year. The author comments on the results as follows: "It will be remembered that the sprayed trees in 1893 yielded at harvest nearly three times as much fruit as did the unsprayed trees, so that on further reflection it is not amazing that they did not greatly excel the latter in yield in 1894. That they were enabled to excel them in quantity and nearly equal them in quality of yield in 1894 after the heavy crop of 1893 is really strong evidence of the permanent beneficial effect of spraying. The permanent injurious effects of the scab fungus on the unsprayed trees in 1893 was no greater, if as great, as the permanent injurious effects of excessive yield of the sprayed trees even though their foliage was kept in good condition by the spray." Beach concludes that "even when trees are sprayed, large annual crops of fruit ought not to be expected unless they are well fed and not permitted to overbear."

This, then, was a case in which the permanent injury due to scab practically balanced that due to an over-production of fruit. In the latter case the injury was accompanied by the remuneration of the crop of 1893, while in the former case it resulted in total loss.

(1895) Beach, S. A. Spraying pear and apple orchards in 1894. New York (Geneva) Agr. Exp. Sta. Bul. 84 : 33-35.
(1906) Crandall, C. S. Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106 : 240.

BIBLIOGRAPHY

In preparing this bibliography the writer has attempted to make it as nearly as possible complete up to date. Since the writer believes the bibliography published by Clinton in 1901 to be adequate to that date, a few of the earlier references have been accepted as given by him and have not been verified. The writer believes that all later papers of importance have been consulted and are listed below.

Aderhold, Rudolf

1894 Die perithecienform von Fusicladium dendriticum Wal. (Venturia chlorospora f. Mali). Deut. Bot. Gesell. Ber. **12**:338–342.

Shows the relationship between *F. dendriticum* on living apple leaves and *V. chlorospora* f. *Mali*, the permanent stage on dead leaves.

1895 Litterarische berichtigung zu dem aufsatze über die perithecienform von Fusicladium dendriticum Wall. Deut. Bot. Gesell. Ber. **13**:54–55.

Speaks of earlier investigations connecting *F. dendriticum* with Venturia stage.

1896 Die Fusicladien unserer obstbäume. Landw. jahrb. **25**:875–914.

Detailed accounts of the scabs of apple, pear, and cherry, and their relation to Venturia stage on dead leaves of these hosts.

1897 Revision der species Venturia chlorospora, inaequalis, und ditricha autorum. Hedw. **36**:80–83.

Describes the different species of Venturia and gives their hyphomycetous stages, placing *Fusicladium dendriticum* under *Venturia inaequalis* (Cooke) Ad.

1899 Arbeiten der botanischen abteilung der Versuchsstation des Kgl. pomologischen Instituts zu Proskau. Centbl. bakt. **2**:**5**:521–522.

Notes *Cephalothecium roseum* following pear scab. Evidently first note of parasitism of this fungus. Summarizes experiments at Proskau on varietal susceptibility.

1900 Die Fusicladien unserer obstbäume. Landw. jahrb. **29**:541–588.

Same as is briefly summarized in Centbl. bakt. 2:**6**:593–595. Aderhold notes that the perithecia are ripe before the blossoms open and that the first infestation appeared about the middle of May, which would make an application after blossoms fall too late for sure protection.

1900 Die Fusicladien unserer obstbäume. Centbl. bakt. **2**:**6**:593–595.

Gives list of host plants and relationships. Also recommends certain measures for control.

1901 Arbeiten der botanischen abteilung der Versuchsstation des Kgl. pomologischen Institutes zu Proskau. Centbl. bakt. **2**:**7**:661–662.

Finds that summer spraying, if given while leaves were young, was as effective as both winter and summer spraying. Winter spraying alone apparently gave some results.

1902 Ein beitrag zur frage der empfänglichkeit der apfelsorten für Fusicladium dendriticum (Wallr.) Fuckel und deren beziehungen zum wetter. Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw. Arb. 2:560–566.

Results of five years investigation of varietal susceptibility to scab. Marked difference noted for some varieties in different seasons.

1903 Kann das Fusicladium von Crataegus und von Sorbus-arten auf den apfelbaum übergehn? Kaiserliches Gesundheitsamt, Biol. Abt. Land- u. Forstw. Arb. 3:436–439.

Cultural and cross-inoculation experiments.

Allen, W. J.

1911 Black spot of the apple and pear. Agr. gaz. N. S. Wales 22:915.

Popular directions for treatment.

Alwood, W. B.

1893 Injurious insects and diseases of plants, with remedial measures for the same. Virginia Agr. Exp. Sta. Bul. 24:24.

Mentions *Fusicladium dendriticum* as cause of one of the serious apple diseases in this State.

André, Ed.

1888 Les Fuscicladium et nos vergers. Revue horticole 60:246–247.

Short description of apple scab.

(Anonymous)

1895–1898 Apple scab. U. S. Agr. Dept. Yearbook 1894:577; 1895:587; 1896:625; 1897:673.

Treatment for prevention of scab.

Arthur, J. C.

1885 Apple scab and leaf blight. New York (Geneva) Agr. Exp. Sta. Ann. rept. 3:370.

Short note on damage caused by this fungus.

Atwood, G. A.

1907 Apple scab. New York State Agr. Dept., Hort. Bur. Inspection bul. 1:12.

Brief note on scab.

Bailey, L. H.

1892 Scab-proof apples. Garden and forest 5:442.

States that there is no marketable scab-proof variety. Baldwin perhaps the least susceptible.

1895 The recent apple failures of western New York. Cornell Univ. Agr. Exp. Sta. Bul. 84:1–34.

Attributes to apple scab the chief cause of failures, and discusses the fungus and methods of combating it.

Ballou, F. H.

1910 Apple culture in Ohio. Ohio Agr. Exp. Sta. Bul. 217:527–559.

The scab was found to be the cause of withering and dropping of blossoms in unsprayed orchards. Records of spraying experiments.

1910 The rejuvenation of orchards. Ohio Agr. Exp. Sta. Bul. 224:117–150.

Reports experiments favoring the use of lime-sulfur as a summer spray for apples.

Beach, S. A.

1897 Wood ashes and apple scab. New York (Geneva) Agr. Exp. Sta. Bul. 140:665–690.

Reports experiments of applying wood ashes to the soil as not preventing scab.

Beach, S. A., and Bailey, L. H.

1900 Spraying in bloom. New York (Geneva) Agr. Exp. Sta. Bul. 196:399–460.

Spraying as soon as blossoms open seems to prevent set of fruit. If blossoms have been opened several days spraying seems to have no bad effect. Laboratory studies showed that poisons or bordeaux, or even lime alone, prevent germination of pollen.

Beach, S. A., and Little, E. E.

1907 Spraying calendar. Iowa Agr. Exp. Sta. Bul. 89:4.

General directions for spraying for scab.

Beach, S. A., Lowe, V. H., and Stewart, F. C.

1899 Common diseases and insects injurious to fruits. New York (Geneva) Agr. Exp. Sta. Bul. 170:385–387.

Short account of life history, and methods of prevention.

Beach, S. A., and Paddock, Wendell

1896 Apple scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. **14**:345–347.

Brief discussion of apple scab and prevention by bordeaux mixture.

Berkeley, M. J.

1855 Why do pears and apples crack? Gard. chron. **1855**:724.

States that this is due to *Spilocæa Pomi*, the fructigenous form of *Helminthosporium Pyrorum*, but does not recognize specific difference between the forms on apple and pear.

Bethune, C. J. S.

1910 Apple scab (Venturia inaequalis) and commercial lime-sulphur. Ontario Agr. Col. and Exp. Farm. Ann. rept. **35**:34–35.

Used lime-sulfur for apple scab with good results.

1911 Spraying experiments. Ontario Agr. Col. and Exp. Farm. Ann. rept. **36**:31.

Reports successful use of lime-sulfur and lead arsenate. Other arsenicals used with lime-sulfur are likely to cause burning.

Bizzozero, G.

1885 Fusicladium dendriticum var. minor Sacc. Fl. Ven. crittog. **1**:510.

Follows Saccardo in giving form on apple as variety of that on pear.

Blair, J. C.

1899 Spraying apple trees, with special reference to scab fungus. Illinois Agr. Exp. Sta. Bul. 54:181–204.

Results of spraying, directions for making fungicide, description of machinery, and like information.

1907 Fruit and orchard investigations. Illinois Agr. Exp. Sta. Circ. 107:1–58.

Note on relative merits of liquid and dust sprays for apples. Reports experiments of three years, 1903–1905. Dust sprays were inefficient in every case.

Bonns, W. W.

1911 Orchard spraying problems and experiments. Maine Agr. Exp. Sta. Bul. 189:33–80.

Reviews past work on sulfur compounds for the control of apple scab, and records results of additional experiments, with notes and observations on spray injury.

Bonorden, H. F.

1851 Fusicladium virescens. Handbuch der allgemeinen mykologie, p. 80.

Describes this as a new genus and species and says in part, " Kommt in Gärten auf veredelten Apfelbäumen vor." Winter gives this as a synonym of the pear-scab organism, and Bonorden's figures certainly more nearly resemble that species than the one on the apple.

Brefeld, O.

1891 Venturia ditricha f. Piri. Unter. gesammt. mykol. **10**:221.

Shows similarity of a stage produced from above fungus to the scab of pear and apple.

Briosi and Cavara

1892 Fusicladium dendriticum (Wallr.) Fckl. Fung. par., no. 140.

Illustrations and specimens of this fungus, together with a short description.

Brooks, Charles

1907 Diseases of the apple. New Hampshire Agr. Exp. Sta. Rept. **17–18**:267–269.

Note containing brief description of apple scab.

1908 Report of the Department of Botany. New Hampshire Agr. Exp. Sta. Rept. **19–20**:330–389.

Notes on apple scab. Late infection. Bordeaux injury. Substitution of lime-sulfur for bordeaux.

1909 Some apple diseases. New Hampshire Agr. Exp. Sta. Bul. 144:111–116.

Popular description and discussion of treatment. Spray injury. Evidence as to ascospore infection.

1910 Report of the Department of Botany. New Hampshire Agr. Exp. Sta. Bul. 151:21–22.

Lime-sulfur likely to require more frequent application in wet seasons than bordeaux. Notes on late infection and importance of spraying before blossoms open.

Burrill, T. J.

1882 Notes on parasitic fungi. Agr. rev. 2:4:86–88.

Account of apple scab.

1883 An orchard scourge. Mississippi Valley Hort. Soc. Trans. 1:202–207.

Account of apple scab and the damage caused by the disease in Illinois.

1901 The apple scab fungus. Illinois Hort. Soc. Trans. 34:86–97.

A popular article on present knowledge of apple scab.

Butz, G. C.

1898 Apples in Pennsylvania. Pennsylvania Agr. Exp. Sta. Bul. 43:13, 16.

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Card, F. W.

1895 Apple-scab in Nebraska. Garden and forest 8:28.

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Chandler, W. H.

1909 Combating diseases and insects of the orchard. Missouri State Bd. Hort. Ann. rept. 3:348, 374–379.

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Chester, F. D.

1888 The scab of the apple and pear. Delaware Agr. Exp. Sta. Bul. 3:6–7.

Short note on above, including preventive measures.

1895 Experiments in the treatment of peach rot and of apple scab. Delaware Agr. Exp. Sta. Bul. 29:18–24.

Favorable results from spraying with bordeaux mixture.

1897 The treatment of plant diseases in 1896. Delaware Agr. Exp. Sta. Bul. 34:14–19.

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Churchill, G. W.

1891 Apple and pear scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. **9**:337–339.

Describes effect of this on leaves and fruit and suggests prevention.

Clark, J. W.

1891 Spraying for the codling moth and apple scab. Missouri Agr. Exp. Sta. Bul. 13:6.

Favorable results from spraying with bordeaux mixture.

Clinton, G. P.

1901 Apple scab. Illinois Agr. Exp. Sta. Bul. 67:109–156.

Botanical studies of the fungus. Studied perfect stage, and demonstrated its connection with Fusicladium thus confirming the work of European investigators.

1904 Diseases of plants cultivated in Connecticut. Connecticut Agr. Exp. Sta. Ann. rept. **27**:301–302.

Brief description of the disease and directions for treatment.

Clinton, G. P., and Britton, W. E.

1910 Tests of summer sprays on apples and peaches in 1910. Connecticut Agr. Exp. Sta. Bienn. rept. **33–34**:584–618.

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Close, C. P.

1900 Plant diseases and insect pests. Utah Agr. Exp. Sta. Bul. 65:67–68.

Note on appearance of scab and remedy.

1905 Dust spraying in Delaware. Delaware Agr. Exp. Sta. Bul. 69:1–7.

Found hydrated lime with copper sulfate, pulverized, and paris green successful. Results very promising.

1906 Third report on dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 76:1–19.

Dusting bordeaux with arsenicals versus spraying. Scab entirely controlled by either method. Bitter rot not well controlled by dusting.

1906 Dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 72:1–23.

Cobb, N. A.

1892 Apple scab. Agr. gaz. N. S. Wales **2**:216, 492.

Reports disease on the increase and suggests use of fungicides.

1893 Apple scab, "Tasmanian black spot." Agr. gaz. N. S. Wales **3**:276–278.

Short botanical account of the fungus and best fungicides for prevention.

Comes, O.

1891 Fusicladium dendriticum Fckl. Crittogamia agraria, pp. 394–397.

Short account of this fungus.

Cooke, M. C.

1866 Sphærella inæqualis Cke. Journ. bot. **4**:248–249.

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Brief popular description of disease and fungus. Advises early spring application of iron sulfate, followed by bordeaux after fruit has set.

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Corbett, L. C.

1900 Fruit diseases and how to treat them. West Virginia Agr. Exp. Sta. Bul. 66:204–206.

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Cordley, A. B.

1904 Apple scab. Oregon Agr. Exp. Sta. Rept. **16**:38–40.

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1909 Lime-sulphur spray preventive of apple scab. Better fruit 3:10:33–35.

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Cordley, A. B., and Jackson, H. S.

1911 Orchard spraying. Oregon Agr. Exp. Sta. Circ. 13:13–15.

Directions for the use of lime-sulfur solution.

Costantin, J.

1888 Fusicladium. Les mucédinées simples, pp. 69–71.

Gives figures and short account of apple scab.

Craig, John, and Van Hook, J. M.

1902 Pink rot, an attendant of apple scab. Cornell Univ. Agr. Exp. Sta. Bul. 207:157–171.

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Crandall, C. S.

1906 Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106:205–242.

An elaborate set of experiments comparing dust and liquid sprays for scab.

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Crawford, F. S.

1886 Report on the Fusicladiums, the codlin moth, and certain other fungus and insect pests attacking apple and pear trees in South Australia. Part I. The apple and pear scab fungi, pp. 7–31.

A popular discussion of the disease, estimates of losses, notes on varietal susceptibility, and the like. Notes on spraying experiments. Suggests use of carbolic acid vapor by placing vessels of the acid in the orchard, as was reported by Mr. Storck to successfully control coffee-leaf disease.

Cuboni, G.

1892 Sulla forma ibernante del Fusicladium dendriticum. Soc. Bot. Ital. Bul. 1892:287–288.

Describes a hibernating condition or stroma found on twigs that under proper conditions of moisture and heat gave rise to the characteristic conidia.

Cummings, M. B.
1909 Apple orchard survey of Niagara county. Cornell Univ. Agr. Exp. Sta. Bul. 262:277-320.

Curtis, M. A.
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Detmers, Freda
1891 Apple scab. Ohio Agr. Exp. Sta. Bul. 4:9:187-192.
Short description of apple-scab fungus and its injury.

Dickens, A., and Headlee, T. J.
1911 Spraying the apple orchard. Kansas Agr. Exp. Sta. Bul. 174:253-292.
Extensive spraying experiments.
1911 Spraying apples. Kansas Agr. Exp. Sta. Circ. 15:1-8.
Spraying experiment comparing lime-sulfur and bordeaux mixture. Lime-sulfur treatment recommended where blotch is not present.

Duggar, B. M.
1909 Apple scab and pear scab. Fungous diseases of plants, pp. 264-271.
A brief account of the disease, including life history, distribution, economic importance, varietal susceptibility, and treatment.

Ellis, J. B.
1892 Dothidea pomigena Schw. The North American Pyrenomycetes, p. 605.
States after examination of Schweinitz' specimen that this is apparently the fructigenous form of *Fusicladium dendriticum*. An examination by Clinton, however, shows this not to be the case.

Emerson, R. A.
1905 Apple scab and cedar rust. Nebraska Agr. Exp. Sta. Bul. 88:1-21.
Results and discussion of spraying experiments. Notes on varietal susceptibility.
1907 Spraying demonstrations in Nebraska apple orchards. Nebraska Agr. Exp. Sta. Bul. 98:1-35.
Spraying experiments in six Nebraska apple orchards. Notes on cost and income.

Emerson, R. A., Howard, R. F., and Westgate, V. V.
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Eriksson, Jakob

1885 Bidrag till kaennedomen om vara odlade vaxters sjukdomar. K. Landtbr. Akad. Exptlfält. Meddel. **1**:61.

1886 Der schorf der obstbäume. Bot. centbl. **26**:345–347.

Abstract of an article published by Erikkson the year before, on scab fungus and damage caused by it in Sweden.

1903 Om fruktträdsskorp och fruktträdsmögel samt medlem till dessa jukdomars bekampande (1. Apfelradszkorp Venturia dendritica) och parontradsskorp (V. pirina). K. Landtbr. Akad. Handl. och Tidskr. **42**:53–71.

Gives description of disease and of fungus, and suggests method of control.

1911 Die rote farbe der fruchtschale und die schorfkrankheit der obstsorten. Zeitsch. pflanzenkr. **21**:129–131.

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Eustace, H. J.

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Cephalothecium roseum following scab, causing pink rot. Proved its parasitism by inoculation.

1908 Investigations on some fruit diseases. New York (Geneva) Agr. Exp. Sta. Bul. 297:47–48.

Scab spots enlarged under coating of bordeaux mixture.

Evans, W. H.

1893 Apple scab. Handb. exp. sta. work **1893**:18.

Short description of scab and means for its prevention.

Ewert, Dr.

1910 Die überwinterung von sommerkonidien pathogener ascomyceten und die widerstandsfähigkeit derselben gegen kälte. Zeitsch. pflanzenkr. **20**:138–139.

Subjected conidia of *Fusicladium pirinum* and *F. dendriticum* to low temperature (16° to 5°) three times, six hours each time. Spores of the pear-scab fungus retained their normal vitality, while but very few of the apple-scab spores germinated after the second freezing.

Fairchild, D. G.

1892 Treatment of apple scab at Brockport. U. S. Agr. Dept., Veg. Path. Div. Bul. 3:62.

Records negative results from spraying with different fungicides because of the absence of scab.

1894 Bordeaux mixture as a fungicide. U. S. Agr. Dept., Veg. Path. Div. Bul. 6:43–44.

Brief historical account of the use of bordeaux mixture for apple scab.

Farrand, T. A.

1905 Report of South Haven sub-station for 1904. Michigan Agr. Exp. Sta. Spec. bul. 30:474–475.

Dust sprays inferior to liquid.

Faurot, F. W.

1903 Report on fungous diseases on cultivated fruits. Missouri Fruit Sta. Bul. 6:4.

Brief note on apple scab.

1906 Demonstration spraying for bitter rot and codling moth. Missouri Fruit Sta. Bul. 15:16.

Note on apple scab and combination treatment for scab, bitter rot, and codling moth.

1908 Spraying versus dusting. Missouri Fruit Sta. Bul. 19:1–24.

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Fischer, F.

1909 Über die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. 19:432–434.

Considers infection occurs through wounds in epidermis. Advises first application of bordeaux before leaves open. Notes on infection and varietal susceptibility.

Frank, A. B.

1880 Fusicladium dendriticum Fckl. Die krankheiten der pflanzen, pp. 587–589.

Short description of this fungus.

Fries, Elias

1819 Spilocæa Pomi Fr. Nov. fl. Suec. 5:79.

Names this fungus here for the first time rather than in Syst. Myc.

1825 Spilocæa. Syst. orb. veg. 1:198.

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1829 Spilocaea Pomi. Syst. myc. 3:504.

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Fuckel, L.

1869 Fusicladium dendriticum (Wllr.). Symb. myc., p. 357.

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Funk, J. H.

1910 Spraying, the sheet-anchor of success. Pennsylvania State Agr. Dept. Bul. 197:85–94.

Practical directions for spraying apple orchards.

Galloway, B. T.

1887 Diseases of the apple caused by fungi. Missouri State Hort. Soc. Ann. rept. **29**:297–299.

Discusses scab and the use of the fungicides then known.

1889 Apple scab. U. S. Agr. Dept. Ann. rept. **1889**:405–412.

Reports on spraying experiments conducted under the writer's direction by Goff and Taft.

1890 Notes on the fungus of apple scab. Michigan Agr. Exp. Sta. Bul. 59:28–29.

Brief description of the fungus.

1892 Treatment of apple, pear, peach, plum, cherry, and quince diseases in the orchard. U. S. Agr. Dept. Ann. rept. **1891**:362–364.

Brief description of spraying experiments conducted under the writer's direction by Goff, bordeaux mixture proving more efficient than copper carbonate.

1892 Experiments in the treatment of apple scab in Wisconsin. U. S. Agr. Dept., Veg. Path. Div. Bul. 3:31–36.

Reports more fully experiments of Goff in 1891.

Galloway, B. T., and Southworth, E. A.

1889 Treatment of apple scab. Journ. myc. **5**:210–214.

Results of spraying experiments conducted in Wisconsin and Michigan with six fungicides, of which eau celeste and ammoniacal solution of copper carbonate were the most effective.

Garman, H.

1890 The apple scab fungus. Kentucky Agr. Exp. Sta. Ann. rept. **2**:46–49.

Description of fungus and discussion of fungicides.

1893 Bordeaux mixture for apple pests. Kentucky Agr. Exp. Sta. Bul. 44:25–26.

Favorable results from spraying with bordeaux mixture for apple scab.

1894 Apple-scab. Kentucky Agr. Exp. Sta. Ann. rept. **6**:53–54.

Very favorable results from spraying a Janet apple tree with bordeaux mixture.

1908 Apple orchard pests in Kentucky. Kentucky Agr. Exp. Sta. Bul. 133:66, 70–71.

Advises spraying before leaves expand, in bad cases. Note on bordeaux and bordeaux dust.

Goethe, R.

1887 Weitere beobachtungen über den apfel und birnenrost. Gartenflora **36**:293–299.

Notes the relationship of Fusicladium stage of scab on apples and pears to mature stage on the dead leaves.

1888 Zur bekämpfung des apfelrostes. Gartenflora 37:263.

Treats of the use and strength of bordeaux mixture as fungicide for apple scab.

1889 Zur bekämpfung des apfelrostes. Gartenflora 38:241.

Notes that scab developed on apples in storage. Suggests the use of sulfur in the storeroom.

Goff, E. S.

1886 An experiment for the prevention of apple scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. 4:260.

Favorable results from spraying a crab-apple tree with hyposulfite of soda.

1888 Applications for the prevention of apple scab. New York (Geneva) Agr. Exp. Sta. Ann. rept. 6:99–101.

Very beneficial results from spraying parts of a crab-apple and a pear tree.

1889 Experiments in the treatment of gooseberry mildew and apple scab. Journ. myc. 5:35–37.

Results of spraying against apple scab with several fungicides.

1890 Treatment of apple scab. Journ. myc. 6:19–21.

Recommends the use of ammoniacal solution of copper carbonate.

1890 Report on the treatment of apple scab. U. S. Agr. Dept., Veg. Path. Div. Bul. 11:22–28.

Results of spraying with different fungicides, of which ammoniacal copper carbonate proved the most effective.

1890 Prevention of apple scab. Wisconsin Agr. Exp. Sta. Bul. 23:1–11.

Description of scab, and results of spraying experiments under the direction of the United States Department of Agriculture, recommending ammoniacal solution of copper carbonate.

1891 Experiment in the treatment of apple scab. Journ. myc. 7:17–22.

Reports favorably on ammoniacal solution of copper carbonate and ammoniacal copper sulfate.

1892 Experiment in the treatment of apple scab. Wisconsin Agr. Exp. Sta. Ann. rept. 8:160–161.

Summarizes results of spraying experiments conducted in 1890.

1893 Preventive treatment for apple scab, etc. Wisconsin Agr. Exp. Sta. Bul. 34:1–13.

Recommends bordeaux mixture.

1893 Experimental treatment for apple scab. Wisconsin Agr. Exp. Sta. Ann. rept. 9:264, 270–271.

Summarizes the results of spraying experiments conducted in Wisconsin.

1894 The apple scab and its prevention. Wisconsin Agr. Exp. Sta. Ann. rept. 10:228–240.

Gives note on scab and results of spraying experiments conducted during several years, especially those of 1892. Recommends bordeaux mixture.

Gossard, H. A.

1908 Spraying apples. Ohio Agr. Exp. Sta. Bul. 191:103–125.

Concludes that "orchards sprayed with lime-sulfur wash in winter do not need treatment with bordeaux mixture before blossoming, unless this ingredient is omitted from the spray applied just after blooming."

1909 Apple spraying in 1908. Ohio Agr. Exp. Sta. Circ. 95:1–8.

When lead arsenate alone was used for the first application, Winesaps fell almost as soon as set, due to scab disease.

1911 Commercial apple orcharding in Ohio. Ohio Agr. Exp. Sta. Circ. 112:1–15.

Reports successful control with lime-sulfur solution.

Green, W. J.

1891 The spraying of orchards. (1) Spraying to prevent apple scab. Ohio Agr. Exp. Sta. Bul. 4:9:193–212.

Records extensive spraying experiments.

1898 Fruit notes. Ohio State Hort. Soc. Ann. rept. 31:11–12.

Shows very beneficial results from spraying with bordeaux mixture for the control of scab.

Green, W. J., Selby, A. D., and Gossard, H. A.

1911 Orchard spraying suggestions for 1911. Ohio Agr. Exp. Sta. Circ. 109:1–3.

Brief directions for spraying.

Halsted, B. D.

1894 Decays of mature apples. New Jersey Agr. Exp. Sta. Ann. rept. 14:369–370.

Brief note on appearance of apple scab.

1895 Some of the more injurious fungi to fruits in 1894. New Jersey Agr. Exp. Sta. Ann. rept. 15:324.

Notes scab as abundant in New Jersey.

Hamilton, J.

1903 Black spot. Queensland agr. journ. 13:555.

Reports good results with the following formula: copper sulfate 4 pounds, alum 2 pounds, lime 3 pounds, water 50 gallons.

Harvey, F. L.

1889 Apple scab or black spot. Maine Agr. Exp. Sta. Ann. rept. 1888:149–151.

Short account of apple scab and means of prevention by spraying.

1890 Apple scab. Maine Agr. Exp. Sta. Ann. rept. 1889:182–184.

Notes on spraying experiments conducted by the United States Department of Agriculture.

Hatch, A. L.

1891 Experiments in treating apple scab. Journ. myc. 7:26.

Speaks of necessity of early spraying and suggests more dilute solutions than were then used.

Henderson, L. F.

1899 Apple scab in the Potlatch. Idaho Agr. Exp. Sta. Bul. 20: 77–95.

Favorable results from the use of bordeaux mixture.

1904 Some experiments with fungus diseases in 1903. Idaho Agr. Exp. Sta. Bul. 39:263–271.

Spraying experiments reported.

1906 Incomplete experiments for 1905. Idaho Agr. Exp. Sta. Rept. **1905**:14–16.

Spraying experiments reported.

1907 Mixed sprays for apple scab and codling moth. Idaho Agr. Exp. Sta. Bul. 55:1–27.

Includes studies concerning times for application of spray.

Hoffman, H.

1863 Cladosporium dendriticum. Index fungorum, p. 37.

Gives references to scab under this name.

Hoskins, T. H.

1892 Orchard spraying. Garden and forest **5**:370–371.

Speaks of need of selection in order to obtain a more hardy variety of apple, resistant to scab.

Huber, Karl

1908 Fusicladium-bekämpfung durch kupperkalkbrühe oder karbolineum. Deut. obstbäume ztg. **1908**:382–387.

Found carbolineum much inferior to bordeaux for controlling scab.

Jackson, H. S.

1913 Apple diseases. Oregon Agr. Exp. Sta. Bienn. crop-pest and hort. rept. **1911–1912**:238–241.

Jarvis, C. D.

1911 Apple growing in New England. Connecticut (Storrs) Agr. Exp. Sta. Bul. 66:256–261.

Advises caution in the use of lime-sulfur for scab; tested on susceptible varieties such as Fall Pippin and Fameuse. Directions for treatment.

Johnston, T. Harvey

1910 Notes on some plant diseases. (C. A scab on apples.) Agr. gaz. N. S. Wales **21**:563–566.

The author refers to a scab due to *Coniothecium chromatosporum*. The accompanying illustration shows typical frost-banding.

Jones, L. R.

1892 The prevention of apple and pear scab by spraying. Vermont Agr. Exp. Sta. Ann. rept. **5**:132–133.

Reports somewhat favorable results from spraying Greening apples with bordeaux mixture and ammoniacal copper carbonate.

1892 Plant diseases. Vermont Agr. Exp. Sta. Bul. 28:30–34.

Reports strong bordeaux mixture more effective than ammoniacal solution of copper carbonate, but injuring the foliage somewhat.

1893 Apple scab. Vermont Agr. Exp. Sta. Ann. rept. **6**:82–83.

States that spraying experiments were failures, due to excessive rains.

1895 Spraying orchards and potato fields. Vermont Agr. Exp. Sta. Bul. 44:83–93.

Describes scab and gives favorable results from spraying with bordeaux mixture.

Jones, L. R., and Morse, W. J.

1902 Scabbing and russeting of apples in 1902. Vermont Agr. Exp. Sta. Ann. rept. **15**:230–231.

Wet season of 1902 gave serious scab infection and induced much russeting of fruit and some spotting of foliage.

1903 Occurrence of plant diseases in Vermont in 1903. Vermont Agr. Exp. Sta. Ann. rept. **16**:154.

Practically no loss from scab. Early season very dry, followed by rainy season.

Jones, L. R., and Orton, W. A.

1898 Spraying for the prevention of apple scab in 1897. Vermont Agr. Exp. Sta. Ann. rept. **11**:195–198.

Report very favorable results from spraying with bordeaux mixture, and show that sprayed trees hold fruit better than do unsprayed trees.

1899 Spraying for the prevention of apple scab. Vermont Agr. Exp. Sta. Ann. rept. **12**:156–159.

Favorable results from the use of bordeaux mixture.

Keffer, C. A.

1894 Spraying apple trees. Missouri Agr. Exp. Sta. Bul. 27:1–24.

As result of numerous experiments, bordeaux mixture reported as largely preventing apple scab.

Kinney, L. F.

1892 The use of fungicides in the treatment of the apple scab. Rhode Island Agr. Exp. Sta. Bul. 15:21–22.

Quotes from Green as to methods and results of spraying.

1895 The scab of the apple and pear. Rhode Island Agr. Exp. Sta. Ann. rept. **7**:185–187.

Brief report on nature of scab.

Kirk, T. W., and Cockayne, A. H.

1908 Plant pathology. Apple scab (Fusicladium dendriticum) and apple Coniothecium (C. chromatosporum). New Zealand Agr. Dept. Ann. rept. **16**:110–111.

Notes on apple scab and a disease often confused with it, said by the authors to be caused by *Coniothecium chromatosporum*. The latter is illustrated, and is apparently identical with russeting of fruit as caused by bordeaux mixture or weather conditions.

Kock, G.

1911 Schorf, Monilia, und weissfleckigkeit auf verschiedenen obstsorten. Oesterr. Landw. Versuchsw. Zeitsch. **14**:209–213.

Varieties resistant and varieties susceptible to scab.

Lamson, H. H.

1892 Spraying against pear and apple scab. New Hampshire Agr. Exp. Sta. Ann. rept. 3–4:217–218, 238–239.

Gives short description of scab and reports favorable results from spraying with bordeaux mixture and ammoniacal solution of copper carbonate.

1894 Some fungus diseases of plants and their treatment. New Hampshire Agr. Exp. Sta. Bul. 19:7–11.

Describes scab and gives favorable results from spraying with bordeaux mixture.

1895 Spraying experiments in 1894. New Hampshire Agr. Exp. Sta. Bul. 27:5–7.

Favorable results from use of bordeaux mixture.

1903 Fungous diseases and spraying. New Hampshire Agr. Exp. Sta. Bul. 101:59–60.

Brief description of disease and directions for spraying. Notes on susceptibility.

Lawrence, W. H.

1904 The apple scab in western Washington. Washington Agr. Exp. Sta. Bul. 64:1–24.

Description of fungus. Notes on twig infection and wintering over of conidia. Also production of conidia from mycelium in dead leaves. Distribution, varietal susceptibility. Inoculation experiments not successful. Spraying experiments.

1906 Apple scab in eastern Washington. Washington Agr. Exp. Sta. Bul. 75:1–14.

Liquid bordeaux versus dust.

1907 Some important plant diseases of Washington. Washington Agr. Exp. Sta. Bul. 83:25–28.

Popular description and methods of control.

Link, H. F.

1825 Spilocaea Pomi. Species plantarum, Linné, **6**:2:86–87.

Description of the fructigenous form of apple scab.

Lloyd, J. W.

1907 Spraying for the codling moth. Illinois Agr. Exp. Sta. Bul. 114:377–429.

Investigations on combined spraying for scab and codling moth.

Lochhead, William

1903 Some injurious insects and fungous diseases of the year 1902. Ontario Agr. Col. and Exp. Farm Ann. rept. **28**:26.

Brief note on prevalence of scab and directions for spraying.

1905 Insects and fungus diseases. Ontario Agr. Col. and Exp. Farm. Ann. rept. **30**:43.

Key to the fungous diseases of the apple.

1909 Three important fungous diseases of the orchard. Quebec Society for the Protection of Plants from Insects and Fungous Diseases. Ann. rept. **1**:53–55.

Popular description of disease and fungus.

Lodeman, E. G.

1892 Spraying apple orchards in a wet season. Cornell Univ. Agr. Exp. Sta. Bul. 48:357–393.

Gives results of spraying with bordeaux mixture, a table of varieties showing their susceptibility to scab, and the chemistry of bordeaux mixture.

1893 The spraying of orchards. Cornell Univ. Agr. Exp. Sta. Bul. 60:265–286.

Results of spraying experiments against apple scab.

1895 The spraying of orchards. Cornell Univ. Agr. Exp. Sta. Bul. 86:101–125.

Gives suggestions concerning and results of spraying apples, chiefly against scab.

Lounsbury, C. P.

1905 Fusicladium of the apple and pear. Cape Good Hope agr. journ. **27**:169–174.

Notes on distribution and injury in Australia and South Africa. Author thinks disease was introduced by nursery stock; possibly by diseased apples, but not so likely. Author thinks disease is carried over mostly on twigs. Old leaves not important.

1908 The Fusicladium disease of the pear and apple. Cape Good Hope agr. journ. **33**:16–32.

Conditions favoring disease and effect on host are described. Author notes that apple scab has a much more limited distribution in South Africa than has pear scab. Notes burning of foliage by use of copper soda spray.

Lovett, A. L.

1911 Spray calendar. Oklahoma Agr. Exp. Sta. Bul. 92:1–16.

Directions for spraying.

McAlpine, D.

1902 Experiments in the treatment of black spot of the apple and pear. Victoria Agr. Dept. Journ. **1**:620–630.

Tests of bordeaux with addition of several other substances.

1902 The fungus causing black spot of the apple and pear. Victoria Agr. Dept. Journ. **1**:703–708.

First observation, and history, of scab in Australia. Life history of fungus, symptoms of disease, and varietal susceptibility are discussed briefly.

1902 Report of the Vegetable Pathologist. Victoria Agr. Dept. Journ. 1:803–804.

Notes on spraying for control of black spot of apples and pears.

1902 Experiments in the treatment of apple and pear scab during 1901–1902. Victoria Agr. Dept. Journ. 1:525–528.

Results of spraying experiments, and notes on varietal susceptibility.

1902 Spraying experiments in 1901–1902 for black spot. Victoria Agr. Dept. Journ. 1:432.

A preliminary report on the spraying experiments for the seasons 1901 and 1902.

1903 Report of the Vegetable Pathologist. Black spot of apple and pear. Victoria Agr. Dept. Journ. 2:250–251.

Tests of various combinations of bordeaux with other substances used on apple and pear. Some experiments are reported more briefly in Bulletin 17 of the department.

1903 Spraying for black spot of the apple. Victoria Agr. Dept. Journ. 2:354–360.

Addition of common salt slightly increased the efficiency of bordeaux, but McAlpine considers it not necessary. Spraying in bloom apparently did not prevent setting of fruit, but the author thinks it advisable to spray earlier.

1904 Black spot of the apple. Victoria Agr. Dept. Bul. 17:1–32.

Appearance of scab in Australia. Varietal susceptibility, and symptoms of attack. Losses. Conditions favoring disease. Spraying experiments.

1907 Experiments with black spot of apple. Victoria Agr. Dept. Journ. 5:362–363.

Compared bordeaux with several proprietary sheep dips, and with phenyl, carbolic acid, and the like. None of the latter gave good results.

1910 Report of the Vegetable Pathologist. Victoria Agr. Dept. Rept. 1907–1910:47–48.

Experiments with lime-water bordeaux.

McCarthy, Gerald

1891 Plant diseases and how to combat them. North Carolina Agr. Exp. Sta. Bul. 76:15.

Short note on scab and means for prevention.

M'Cormack, E. F.

1910 Apple scab (*Venturia pomi*). Indiana State Entomologist. Ann. rept. 3:145–147.

Popular description of disease and directions for control.

McCready, S. B.

1911 Spraying for apple scab. Ontario Agr. Col. and Exp. Farm Ann. rept. 36:42.

Macoun, W. T.

1901 Apple culture. Canadian Agr. Dept., Cent. Exp. Farm. Bul. 37:67–68.

Notes this fungus as being very troublesome during recent years.

1902 Spraying. Canadian Exp. Farms. Rept. **1901**:109.
Notes on spraying apples for scab.

1903 Spraying. Canadian Exp. Farms. Rept. **1902**:110–111.
Notes loss due to omission of late spraying. Note on bordeaux russeting of apples.

Malley, C. W.

1909 Spraying for apple scab or black spot. Cape Good Hope agr. journ. **35**:202–211.
Spraying experiments. At least half the fruit dropped from unsprayed trees. Third spraying caused some injury. Bordeaux injury found to occur as seriously when a small quantity of copper sulfate was used as when the quantity was large. A few trees were sprayed while in blossom and most of the blossoms were killed.

Marchal, E.

1907 Les principaux maladies du pommier. Brussels agr. bul. **23**: 56–58.
Short description of disease and directions for treatment.

1907 Rapport sur les observations effectives par le service pathologique de l'Institute Agricole de l'État en 1906. Brussels agr. bul. **23**:41.
Reports occurrence of apple scab.

Marlatt, C. L., and Orton, W. A.

1906 The control of the codling moth and apple scab. U. S. Agr. Dept. Farmers' bul. 247:12–21.
Discussion of the disease and methods of control.

Massee, G.

1899 Apple scab. A text-book of plant diseases, pp. 302–304, 435.
Short botanical description of this fungus, together with preventive measures.

1907 Apple scab. A text-book of plant diseases, pp. 302–304.
Brief description of disease, giving authorized methods of control.

Massey, W. F.

1893 The culture of orchard and garden fruits. North Carolina Agr. Exp. Sta. Bul. 92:87–88.
General information concerning scab, and list of varieties most and least liable to attack.

1900 The diseases and insects affecting apple trees in North Carolina, with suggestions for their destruction. North Carolina State Bd. Agr. Bul. **21**:28–39.
Discussion of treatment for apple diseases in general.

Maynard, S. T.

1891 Fungicides and insecticides on the apple, pear, and plum. Massachusetts (Hatch) Agr. Exp. Sta. Bul. 11:12–16.
Reports various spraying experiments, which were not very successful in preventing apple scab.

Mohr, Karl

1900 Bericht über die im sommer 1899 angestellten versuche behufs bekämpfung pflanzlicher schmarotzer auf reben und kernobst. Zeitsch. pflanzenkr. **10**:270–274.

Reports the use of basic calcium sulfid as a summer spray for apple and pear scab and for grape mildews.

1901 Versuche über die pilztötenden eigenschaften des sulfurins. Zeitsch. pflanzenkr. **11**:98–99.

Reports successful use of sulfurin (chemically calcium polysulfid) for apple and pear scab and also for several other fungous diseases.

Morris, O. M., and Nicholson, J. F.

1908 Orchard spraying. Oklahoma Agr. Exp. Sta. Bul. 76:27–28.

Brief account of apple scab.

Morse, W. J.

1910 Notes on plant diseases in 1908. Maine Agr. Exp. Sta. Bul. 164:1–28.

Notes on self-boiled lime-sulfur as a substitute for bordeaux mixture for apple scab. Notes on late infection.

Morse, W. J., and Lewis, C. E.

1911 Maine apple diseases. Maine Agr. Exp. Sta. Bul. 185:352–355, 390.

Description of the disease and notes on the life history of the fungus. Storage infection noted.

Munson, W. M.

1892 Spraying experiments. Maine Agr. Exp. Sta. Ann. rept. **1891**:110–118.

Account of scab and results of favorable spraying experiments with eau celeste and ammoniacal solution of copper carbonate.

1892 Spraying experiments. Maine Agr. Exp. Sta. Ann. rept. **1892**:92–98.

Favorable results from spraying with eau celeste against scab.

1894 Notes of spraying experiments. Maine Agr. Exp. Sta. Ann. rept. **1893**:124–128.

Favorable results from spraying with bordeaux against scab.

1903 Experiments in orchard culture. Maine Agr. Exp. Sta. Bul. 89:16–18.

The use of an excess of potash as fertilizer did not ward off attacks of scab.

1905 Summary of experiments in practical horticulture. Maine Agr. Exp. Sta. Bul. 113:26–27.

Ammoniacal copper carbonate was less satisfactory than bordeaux.

1906 Orchard notes. Maine Agr. Exp. Sta. Bul. 128:69–71.

Notes on and directions for spraying for scab. Notes on pink rot following scab.

1908 Orchard notes, 1907. Maine Agr. Exp. Sta. Bul. 155:143.
Notes on spraying for scab, and directions for same.

1909 Apple enemies and how to fight them. West Virginia Agr. Exp. Sta. Bul. 121:353–366.
General directions for spraying apple trees.

Niessl, G. von

1881 Didymosphæria inæqualis (Cke.) Nssl. Fung. Eur., Rabenhorst, no. 2663.
Changes to above name from *Sphærella inæqualis* Cke.

1898 Bemerkung über "Venturia" inæqualis (Cooke) und verwandte formen. Hedw. beiblatt 37:1–2.
Criticises Aderhold for placing above species under genus Venturia because of presence of bristles around ostiolum.

Norton, J. B. S., and Norman, A. J.

1910 Controlling fungous diseases. Maryland Agr. Exp. Sta. Bul. 143:177–187, 200.
Compares self-boiled lime-sulfur, bordeaux, and sulfocide. Finds bordeaux the most satisfactory of the three.

Norton, J. B. S., and Symons, T. B.

1907 Control of insect pests and diseases of Maryland crops. Maryland Agr. Exp. Sta. Bul. 115:176–177.
Contains alphabetical list of cultivated crops, with notes on their pests and diseases including apple scab.

Paddock, Wendell

1901 Plant diseases of 1901. Colorado Agr. Exp. Sta. Bul. 69:9.
Note on bordeaux injury. Serious on Ben Davis apples.

Pammel, L. H.

1885 Apple scab and leaf blight. Prairie farmer 57:746.
Gives abstract of article by Trelease.

1891 Treatment of fungus diseases. Iowa Agr. Exp. Sta. Bul. 13:48–49.
Gives copper carbonate as fungicide for this disease.

Peck, C. H.

1873 Spilocæa Pomi Fr. New York State Cabinet Nat. Hist. Rept. 23:55.
Reports scab common on apples in New York in 1869.

1881 Fusicladium dendriticum Wallr. New York State Mus. Nat. Hist. Rept. 34:32–33.
Gives short account of above, including with it forms on pear and other hosts.

Persoon, C. H.

1822 Fumago Mali. Myc. Eur. 1:9.
Brief description of above fungus, which may possibly be apple scab.

Pickett, B. S.

1908 Spraying apple orchards for insects and fungi. Illinois Agr. Exp. Sta. Circ. 120:1–36.

General directions for spraying, with spray calendar.

Piper, C. V.

1893 Common fungous diseases and methods of prevention. Washington Agr. Exp. Sta. Bul. 8:138.

Writes briefly about apple scab and its prevention by spraying.

1902 Orchard enemies in the Pacific Northwest. U. S. Agr. Dept. Farmers' bul. 153:33–34.

Notes on distribution of apple scab in the Northwest, description, and directions for treatment.

Powell, G. H.

1894 The apple-scab. Garden and forest **7**:297.

List of varieties most and least affected by scab, as determined at Cornell University Horticultural Experiment Station.

Quaintance, A. L., and Scott, W. M.

1912 The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Agr. Dept. Farmers' bul. 492:23–26.

Quinn, G.

1907 Seasonable notes on some orchard pests. South Australia Agr. Dept. Journ. **10**:14.

Brief notes on apple scab. Directions for spraying.

Reddick, D.

1913 The apple scab situation. West. New York Hort. Soc. Proc. **58**:86–90.

1913 Factors influencing successful orchard spraying. New York State Fruit Growers' Assoc. Proc. **12**:51–54.

Roberts, J. W.

1911 The dilute lime-sulphur sprays versus bordeaux mixtures for apple diseases. Is bordeaux to be abandoned? Indiana Hort. Soc. Trans. **1910**:82–93.

Control experiment.

Roumeguère, C.

1890 Fusicladium dendriticum forma microsperma. Fungi sel. exs., no. 5592.

Describes briefly this new form, of which a specimen is given.

Ruggles, A. G., and Stakman, E. C.

1911 Orchard and garden spraying. Minnesota Agr. Exp. Sta. Bul. 121:1–32.

Brief description of scab and methods of treatment.

Saccardo, P. A.

1881 Fusicladium dendriticum (Wallr.) Fckl. var. minor. Fungi Italici, f. 782.

Gives form on apple as variety of that on pear.

1886 Fusicladium dendriticum (Wallr.) Fckl. Syll. fung. **4**:345.

Botanical description of above species.

1886 Fusicladium dendriticum (Wallr.) Fckl. var. Soraueri (Thüm.). Syll. fung. **4**:346.

Reduces von Thümen's *Napicladium Soraueri* to variety of apple-scab fungus.

Salmon, E. S.

1908 Apple scab or black spot. London Bd. Agr. Journ. **15**:182–195.

Scab said to cause considerable damage in England. Susceptibility of varieties discussed. Directions for bordeaux treatment. For late infection ammoniacal copper carbonate should be used. Suggests winter washing of trees with strong copper-sulfate solution when twigs are infected. Notes finding scab on twigs. First time reported in England.

1908 Apple scab or black spot and its treatment. Southeastern Agr. Col. (Wye, Kent). Journ. **17**:304–315.

Importance of the disease in England.

1909 Black spot or apple scab. Southeastern Agr. Col. (Wye, Kent). Journ. **18**:267–270.

Control experiments. Twig infection.

1910 A lime-sulphur wash for use on foliage. London Bd. Agr. Journ. **17**:184–189.

Used lime-sulfur wash of a density of 1.01 for hop mildew (*Sphaerotheca humuli*), gooseberry mildew (*S. mors-uvae*), and apple scab. Results good on all, so far as tested.

1910 Injury to foliage by bordeaux mixture. London Bd. Agr. Journ. **17**:103–114.

Discusses bordeaux injury on both fruit and foliage. Notes injury due to previous attack by the fungus. Russeting of fruit due to weather conditions. Recommends spraying susceptible varieties very lightly. Advises that no other spray than bordeaux be used for scab. Lime-sulfur is unquestionably inferior to bordeaux, although some success has attended its use in the United States.

Sanderson, E. D., Headlee, T. J., and Brooks, Charles

1907 Spraying the apple orchard. New Hampshire Agr. Exp. Sta. Bul. 131:9–56.

Popular descriptions of apple scab and results of spraying experiments. A net profit of eighty per cent for the first year is reported, as a result of spraying for scab and codling moth.

Scalia, G.

1901 Intorno ad una nuova forma di Fusicladium dendriticum (Wallr.) Fckl. Accad. Gioenia d. Catania. Boll. **70**:1–5. 1901. Abs. in Bot. centbl. **89**:398. 1902.

Fusicladium on Japanese loquat seems to have affinities with *F. dendriticum* and *F. eriobothryae*, and the name *F. dendriticum eriobothryae-japonicae* is given it. (Abstract consulted.)

Schander, R.

1909 Zur karbolineumfrage. Deut. landw. presse **36**:63–64.

Reports spraying experiments, testing carbolineum which failed to control scab.

Schroeter, J.

1894 Fusicladium dendriticum Wallroth. Krypt.-fl. von Schles. 3:352.

Describes scab on apple and pear as a conidial stage of *Venturia chlorospora.*

Schweinitz, L. D. de

1834 Spilocæa fructigena aut Pomi Lk. Syn. F. N. A., p. 297.

Reports above not rare on Newton Pippin. Seems to have originated the specific name *fructigena.*

Scott, W. M.

1906 The control of apple bitter-rot. U. S. Agr. Dept., Plant Indus. Bur. Bul. 93:33.

Directions for combined treatment for scab and bitter rot.

1908 Self-boiled lime-sulfur mixture as a promising fungicide. U. S. Agr. Dept., Plant Indus. Bur. Circ. 1:12.

Reports no definite data, but favorable indications as to the control of apple scab by self-boiled lime-sulfur.

1909 Lime-sulfur mixtures for the summer spraying of orchards. U. S. Agr. Dept., Plant Indus. Bur. Circ. 27:15–17.

Commercial and self-boiled lime-sulfur used for control of scab, in comparison with bordeaux mixture.

1910 The substitution of lime-sulphur preparations for bordeaux mixture in the treatment of apple diseases. U. S. Agr. Dept., Plant Indus. Bur. Circ. 54:1–15.

Results of experiments in Virginia, Michigan, and Arkansas, during the season of 1909. Lime-sulfur solution seemed the more promising.

1910 The use of lime-sulphur sprays in the summer spraying of Virginia apple orchards. Virginia Agr. Exp. Sta. Bul. 188: 1–16.

Lime-sulfur was as effective as bordeaux for apple scab, and caused no russeting of fruit as did bordeaux.

1911 The use of dilute lime-sulphur for the control of apple diseases. Illinois Hort. Soc. Trans. **44**:138–145.

Summarizes results of experiments favoring the use of lime-sulfur for scab.

Scott, W. M., and Quaintance, A. L.

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1856 Contributions to New England mycology. Boston Soc. Nat. Hist. Proc. 5:329.
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1910 Some suggestions on apple growing in Rhode Island. Rhode Island State Bd. Agr. Rept. 25:151–153, 155.
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Directions for spraying with bordeaux mixture.

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1896 Spraying experiment. Arkansas Agr. Exp. Sta. Bul. 39:20–22.

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Streinz, W. M.

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Sturgis, W. C.

1892 Scab. Connecticut Agr. Exp. Sta. Bul. 111:3–4.

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Short note on apple scab.

1894 Spraying for scab of apple and pear. Connecticut Agr. Exp. Sta. Ann. rept. **17**:72–73.
Results of spraying experiments including winter and summer treatments.

1901 Scab [Fusicladium dendriticum (Wallr.) Fckl.]. Connecticut Agr. Exp. Sta. Ann. rept. **24**:258.
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1890 Report on the experiments made in 1889 in the treatment of apple scab in Michigan. Michigan Agr. Exp. Sta. Bul. 59:30–42.
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Brief directions for spraying for scab and codling moth.

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1909 Annual report of the South Haven sub-station for 1908. Michigan Agr. Exp. Sta. Spec. bul. 48:16–24.
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Note suggesting use of lime-sulfur on apple trees.

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1875 Napicladium, eine neue hyphomyceten-gattung. Hedw. **14**: 3-4.

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Tillinghast, J. A., and Adams, G. E.

1899 Suggestions as to spraying. Rhode Island Agr. Exp. Sta. Bul. 52: 20-21.

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Trelease, William

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Voges, Ernst

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1910 Die bekämpfung des Fusicladium. Zeitsch. pflanzenkr. **20**: 385-393.

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Wallace, Errett

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1909 The value of lime-sulphur solutions as fungicides. Amer. Pomol. Soc. Proc. **1909**:112–113.

Control experiments with lime-sulfur.

1910 Spray injury induced by lime-sulfur preparations. Cornell Univ. Agr. Exp. Sta. Bul. 288:101–137.

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1910 Venturia inæqualis, ascospore dissemination and infection. Science n. s. **31**:753–754.

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1911 Lime-sulfur as a summer spray. Cornell Univ. Agr. Exp. Sta. Bul. 289:139–162.

Popular account of experiments in the control of apple scab. Various modifications of lime-sulfur preparations are compared with one another and with bordeaux mixture. Early attack of scab was found to be largely cause of poor set of fruit in 1910.

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1911 Studies of the fungicidal value of lime-sulfur preparations. Cornell Univ. Agr. Exp. Sta. Bul. 290:163–207.

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Wallroth, F. G.

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Notes on spraying. Estimate of profit due to spraying.

1906 Spraying. New Jersey Agr. Exp. Sta. Bul. 194:12–15.

Popular notes on spraying apples, with directions.

1909 Elements of agriculture, p. 253.

Brief note on apple scab.

Warren, G. F., and Voorhees, J. A.

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Watkins, O. S.

1911 Summary of various spraying experiments for the summer of 1910. Illinois Hort. Soc. Trans. 44:145–169.
Bordeaux mixture considered more effective than lime-sulfur.

Weed, C. M.

1890 Apple scab. Ohio Agr. Exp. Sta. Bul. 14:188.
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Whetzel, H. H., and Stewart, F. C.

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Brief directions for controlling scab.

Whitten, J. C.

1895 Spraying orchards and vineyards. Missouri Agr. Exp. Sta. Bul. 31:1–19.
Favorable results from spraying with bordeaux mixture.

Wilcox, E. M.

1905 Diseases of the apple, cherry, peach, pear, and plum, with methods of treatment. Alabama Agr. Exp. Sta. Bul. 132:97–102.
Brief description, with directions for control.

Williams, T. A.

1893 Common fungous and insect foes of farm and garden. South Dakota Agr. Exp. Sta. Bul. 35:79.
Gives short note on apple scab.

Winter, Georg

1875 Ueber Napicladium soraueri Thümen. Hedw. 14:35–36.
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Gives this name for first time to specimens on apple leaves.

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CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
OF THE COLLEGE OF AGRICULTURE

SOME RELATIONS OF CERTAIN HIGHER PLANTS TO THE FORMATION OF NITRATES IN SOILS

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SOME RELATIONS OF CERTAIN HIGHER PLANTS TO THE FORMATION OF NITRATES IN SOILS

T. Lyttleton Lyon and James A. Bizzell

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INTRODUCTION

There are several forms in which nitrogen occurs in soils. The uncombined nitrogen of the soil air constitutes the largest supply because of its diffusibility with the atmospheric air. Next in amount is the nitrogen of organic compounds, ranging from .05 to .3 per cent on ordinary arable land and always slightly, but appreciably, soluble in soil water. In upland cultivated soils the nitrogen of nitrate salts forms the next largest supply, but rarely exceeds 20 per cent of the total combined nitrogen of the soil. Curiously enough, the heavy, and consequently poorly aerated, soils usually contain more nitrates than do lighter soils, and Fischer (1911)* has found that nitrate formation is more rapid in such soils. In forest, swamp, and inundated soils the nitrogen of ammonium salts and nitrites forms a larger proportion of the soil nitrogen than does the nitrate nitrogen, but in well-aerated soil these compounds exist in very small quantities.

The utilization of nitrogen in these various forms by agricultural plants has furnished the incentive for a large amount of able and important experimentation, which has resulted in the definite and final demonstration of certain facts and in the partial solution of some questions relating to the agricultural availability of nitrogen in its various soil conditions. The utilization of atmospheric nitrogen by leguminous plants, for instance, has been established beyond question; but the extent to which this form of nitrogen may be utilized by other plants, or the identity of the plants that participate in its use, are subjects on which opinions differ and which are still being investigated. The study of the degree to which the nitrogen of organic compounds is available to higher plants has enlisted the efforts of numerous investigators and has been only partially worked out.

While nitrate nitrogen is generally conceded to be the form best suited

* Dates in parenthesis refer to bibliography.

to the use of most higher plants, there is undoubtedly a difference between plants of different species in their relation to the nitrate nitrogen content of the soil. The disappearance of nitrate nitrogen from the soil during the growth of different kinds of plants is not always proportional to the total quantity of nitrogen removed by the crop. Thus, it is greater for oats than for maize, although the latter crop may contain a much larger quantity of nitrogen. Both the question of a possible influence of certain plants on the process of nitrate formation in the soil, and that of the degree to which some plants may use forms of nitrogen other than nitrates, are raised by these phenomena.

Boussingault first demonstrated the importance of nitrates for higher plants. Previous to that time ammonia had been considered the chief source of nitrogen, and still earlier humus had been considered the source. Liebig gave the weight of his influence in favor of ammonia as the supply. He was unaware, of course, of the transformation of ammonia nitrogen into nitrates in the soil. Since the publication of the experiments by Boussingault and the later work on nitrification, there has been a tendency to consider nitrate nitrogen as the only available supply of nitrogen for autotrophic plants.

It is questionable whether nitrates are so universally and decidedly important to plant growth as has been commonly supposed since the time of Boussingault. The preference that swamp rice plants exhibit for ammonium salts, as proved by Kellner (1884) and also by Kelley (1911), indicates an adaptation of this variety to the prevailing condition of its environment, which must be reversed on its transfer to upland soils. Other plants also may adapt themselves to the use of the more abundant form of nitrogen.

Ammonium salts are toxic to most higher plants except in very dilute solutions. Mazé (1900) obtained as great a growth of maize with a very dilute solution of ammonium sulfate as with a correspondingly strong solution of nitrate. It is possible that the toxic action has masked the nutritive value of ammonia in many experiments.

In a similar way results of experiments with ammonium salts applied to soils may have been influenced by the acid residue remaining when the nitrogen was removed.

Hutchinson and Miller (1911) found that peas obtained nitrogen from ammonium salts as readily as they did from sodium nitrate, but that

wheat plants, although able to obtain nitrogen directly from ammonium salts, grew much better in a solution containing nitrates.

One feature brought out by the numerous experiments with ammonium salts is the difference between plants of various kinds in respect to their ability to absorb ammonium compounds. When fully worked out, the degree to which this aptitude is possessed may serve as a practical guide in the fertilizing of agricultural plants.

One of the early beliefs in regard to plant nutrition was that organic matter as such was directly absorbed by higher plants. This opinion was afterwards entirely replaced by the mineral theory propounded by Liebig; and still later the discovery of the nitrifying process almost disposed completely of the belief that organic nitrogen was a food for higher plants. Possibly plants of different species vary in their ability to use nitrogen in the different organic forms. It is also quite likely that the stage of growth of the plant determines, in some measure, the ability of the plant to utilize organic forms of nitrogen.

The relation that the various nitrogenous compounds of the soil bear to the physiological processes concerned in absorption is an almost untouched subject. It is possible that changes occur at the root surface through the action of enzymes secreted by the plant. Nitrates have been found in plants, and so also has ammonia. It is generally held that these substances are absorbed directly.

Nitrate-reducing enzymes have been found in several species of plants, and it seems probable that reduction is the first step in the assimilation of nitrates. Ritter (1912) found that the first process in the utilization of nitrates by certain molds is a reduction of nitrate to nitrite. If amids are an intermediate step in the formation of proteids in the plant, reduction is necessary.

It may be that the formation of nitrates is merely a process that facilitates the absorption of nitrogen by reason of the ease with which nitrates pass through the semipermeable membrane of the root cells, and that the most economical use of soil nitrogen would not necessitate the formation of large quantities of nitrates for the growth of many of the higher plants.

EXPERIMENTS BY OTHER INVESTIGATORS

Experiments by the writers of this paper and by a number of other investigators indicate that crops differ from one another in respect to the

occurrence of nitrates in the soil on which they grow. For any one soil the nitrate content is largely dependent on the kind of crop grown. Furthermore, the stage of growth of any particular plant has a characteristic relation to the nitrate content of the soil. The extensive literature bearing on the nitrate content of soils contains a number of instances illustrating this relationship between the soil and the crop growing on it, and these may be so classified as to bring out definite relations.

Experiments showing different nitrate contents of soils under different crops

In an extensive series of field experiments in which nitrates were determined in samples of soil taken under several crops, King and Whitson (1901) found that, for the four crops named, nitrates were highest during the growing season under maize, next under potatoes, and lowest under alfalfa and clover.

Stewart and Greaves (1912), in another extensive set of experiments extending over several years, found the nitrate content under maize, potatoes, oats, and alfalfa to rank in the order named.

In field soil planted to different crops Wollny (1897) found that the quantities of nitric nitrogen, expressed in kilograms per German acre, were 9.2 under beans, 22 in fallow, and 1.2 under wheat.

Brown (1912) sampled soil of neighboring plats that continuously for several years had grown maize and clover, respectively, and found that the processes of ammonification and nitrification were more rapid in the soil planted to maize.

Voorhees, Lipman, and Brown (1907) inoculated a modified Omelianski's solution with soil that had grown oats, soil that had grown crimson clover, and soil that remained unplanted during the period required to mature the crops. The resulting formation of nitrates was greater in the solutions inoculated with the unplanted soil than in those inoculated with the soil planted to either of the crops. The quantity of nitrates found, however, was small. An ammonification test resulted in a greater production of ammonia from the planted than from the unplanted soil.

Brown and MacIntire (1910) found the average nitrate content for the growing season to be: under maize, 55.5 parts per million of the dry weight of the soil; under oats, 18 parts per million; under wheat, 7.9 parts per million; under grass, 1.4 part per million. The average moisture

content of the soil under these crops ranged from 24.1 per cent for maize to 26.6 per cent for wheat. The difference in nitrate content, therefore, could not be attributed to differences in soil moisture.

In all these experiments nitrates reached their lowest point under grass before they did under wheat or oats, and under wheat and oats before they did under maize; but even after the minimum nitrate content was reached under all crops they stood in the same order. As these experiments represent soils in Germany, New Jersey, Pennsylvania, Wisconsin, and Utah, thus ranging from a humid to an arid region, the agreement in the relation of the nitrogen content of the soil to the plants used in the experiments is certainly significant.

Experiments showing higher nitrate content under plants than in fallow land

The figures given by Stewart and Greaves (1909), in a study of nitrates in irrigated soils planted to maize, potatoes, and alfalfa, and also on land fallow during a period of three years and planted to oats one year, show nitrates to be higher under maize than in fallow land at certain stages in the growth of the crop, and in some cases the same was true with potatoes. The highest nitrate content under these crops occurred at about the time of their most active growth and in the first foot or the first two feet of soil.

King and Whitson (1902) report an experiment in which one of two contiguous plats of oats had a crop entirely removed on June 20, on which date determinations of nitrates were made in the soil of both plats to a depth of four feet. The crop on the harvested plat was weighed and the dry matter determined. At the end of nineteen days nitrates were again determined in both plats, the remaining oats were harvested and weighed, and the dry matter was determined. No determinations of nitrogen were made with the crop, but the gain in nitrogen for the nineteen days was calculated from the dry weight on the basis of average analyses for oat plants at that stage. The gain in nitrogen in the oat plants which had been growing for nineteen days, minus the loss of nitrates during that time, was twice as great as could be accounted for by the gain of nitrates on the bare plat. No account was taken of the nitrogen in the plant roots, which would make a still greater difference. Evidently there was a much larger supply of available nitrogen in the soil growing oats than was represented by the nitric nitrogen of the bare plat, and this supply was due either to a

more active nitrate formation in the soil growing oats or to the utilization of some form of nitrogen other than nitrates. The investigators did not think that a decomposition of nitrates could account for it.

Similar results with clover were obtained by the same investigators, but since clover is a legume this may be accounted for by processes already understood.

Results reported by Jensen (1910) showed that soil planted to maize contained more nitrates during the first part of July than did fallow land.

Fraps (1908) found that fifty to one hundred per cent more nitrogen was removed by maize plants in the first nine weeks of their growth than was apparently transformed from organic compounds into ammonium and nitrate salts in the same time.

Bower (1912) determined nitrates in soil of unplanted plats, both cultivated and uncultivated, and in maize plats cultivated and uncultivated. In both the cultivated and the uncultivated plats nitrates under the maize were higher during July than in the bare soil.

In the experiments cited showing a higher nitrate content of soil under maize than in fallow land, this condition obtained during the period of active growth and usually before full bloom. The experiments in which an unaccountable nitrogen supply was indicated also relate to the earlier stages of growth. They agree in suggesting an activity in nitrate formation under certain plants during early growth which does not obtain in unplanted soil.

Experiments indicating a depressed nitrate formation under plants

Brown and MacIntire (1910) found that the nitrates in oat land did not increase after the crop began to mature until after plowing in the fall. The plowing was done on August 20.

Leather (1912) reports experiments in which large tanks containing soil were planted or fallowed and nitrate nitrogen was determined in the drainage water. Of these gauges, numbers 1 and 3 were cropped and numbers 2 and 4 were fallowed. In 1909 the rainfall was sufficient to replace entirely the water in the gauges. The nitrogen in the crops of 1908 and 1909 plus the nitrogen in the drainage water for that period should be, Leather thinks, equal to the nitrogen in the drainage water of the fallow gauges. He shows by the following figures, however, that this is not the case:

Gauge No.	1	2	3	4
	Pounds per acre			
Nitric nitrogen in drainage water	+261.5	+51.1	+209.6	+53.9
Nitrogen in manure used	......	—50.0	......	—50.0
Nitrogen in maize crop, 1908	......	+49.0	......	+44.7
Nitrogen in wheat crop, 1908–1909	......	+ 7.9	......	+ 7.9
Nitrogen in maize crop, 1909	......	+38.6	......	+31.2
Nitrogen estimated to have been in roots of the three crops	......	+31.8	......	+27.9
Net total	+261.5	+128.4	+209.6	+115.6

It thus appears that there is a smaller quantity of soluble nitrogen in the cropped than in the fallow gauges, and that, either directly or indirectly, the presence of the higher plant prevented the formation of nitrates.

At Grignon it was found by Dehérain (1902), as the result of experiments with large vegetative tanks, that the loss of nitrogen in drainage water from fallow soil amounted to 200 kilograms per hectare; from soil planted to maize, harvested before maturity, the removal of nitrogen by the crop plus that in the drainage water amounted to slightly less than that in the drainage water from the fallow soil; from soil planted to oats the nitrogen in the crop and in the drainage water amounted to only 63 kilograms per hectare; and from soil continuously in grass the drainage water contained almost no nitrogen.

Dehérain attributes this to the drying out of the soil by the growing plants during the season most favorable to nitrate formation, except in the case of maize, which was planted later. Leather (1912), who obtained somewhat similar results, does not accept this explanation.

The writers of this paper (1911) advanced the hypothesis that certain higher plants exert a stimulating or a depressing influence on the process of nitrate formation, depending on the stage of growth. Most of the experiments cited above were performed before that time, and, since no suggestion had previously been made as to any relation between higher plants and nitrate formation, many data that might have thrown light on that subject have probably been omitted from the publications. However, Leather, who published his results in 1912, has considered his data with regard to this hypothesis and expresses himself as considering it a possible explanation for the results obtained by Dehérain and by himself.

INVESTIGATIONS AT THE CORNELL UNIVERSITY AGRICULTURAL EXPERIMENT STATION

In connection with a study of the nitrogen relations of the timothy plant, determinations of nitrates were made during the summers of 1907, 1908, and 1909, in samples of soil taken from field plats under timothy, maize, and oats in rotation. The results of these experiments showed such characteristic relations of the respective plants to the nitrate content of the soil that the study has now been continued for six years. The present paper deals mainly with the field experiments in the investigation.

There were two conditions of the experiments which probably contributed largely to making the relationship obvious. These were (1) the heavy clay soil, which made the movement of nitrates very slow and hence emphasized the relationship between the plant at any particular stage of growth and the nitrate content of the soil; (2) the division of each plat into sections, of which one was always kept bare but received the same soil treatment as the planted sections of the plat and thus permitted a constant comparison of the nitrates in the planted and the unplanted sections.

Experiments on plats manured for timothy

Experiment plats one tenth acre in size were used in this experiment. They were in a rotation of timothy three years and maize, oats, wheat, each one year. Most of them had been fertilized in different ways for timothy, but received no fertilizer for the grain crops that followed. Fertilizers were applied to the timothy in 1905, 1906, and 1907. Manure was applied to the timothy in 1905 and 1907. There were twenty-two plats in all. Their treatment is shown in Table 1:

TABLE 1. Fertilizer Treatment (per Acre) of Plats Manured for Timothy

Plat	Treatment	Plat	Treatment
711	No fertiliser	717	No fertiliser
712	320 pounds rock superphosphate	718	320 pounds rock superphosphate 80 pounds muriate of potash
713	80 pounds muriate of potash	719	160 pounds nitrate of soda 80 pounds muriate of potash
714	No fertiliser	720	No fertiliser
715	160 pounds nitrate of soda	721	160 pounds nitrate of soda 80 pounds muriate of potash 320 pounds rock superphosphate
716	320 pounds rock superphosphate 160 pounds nitrate of soda		

TABLE 1 (*continued*)

Plat	Treatment	Plat	Treatment
722	160 pounds nitrate of soda 80 pounds muriate of potash 640 pounds rock superphosphate	727	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds rock superphosphate
723	No fertiliser	728	640 pounds nitrate of soda 80 pounds muriate of potash 320 pounds rock superphosphate
724	320 pounds nitrate of soda 80 pounds muriate of potash 640 pounds rock superphosphate	729	No fertiliser
725	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds rock superphosphate	730	No fertiliser
		731	10 tons manure, 1905, 1907
726	No fertiliser	732	20 tons manure, 1905, 1907

On these plats samples of soil were taken, to a depth of eight inches, at intervals during the growing season and after the timothy and oats had been removed. The entire twenty-two plats were sampled on the same day or on two consecutive days. The samples were removed from the earth by means of a soil auger. Twelve borings were removed from each plat and thoroughly mixed on an oilcloth surface, and a pint sample was placed in a glass jar. The sample was brought to the laboratory and moisture and nitrates were determined -- the former by drying to constant weight at the temperature of boiling water; the latter by the phenol-disulfonic-acid method, comparisons with a standard nitrate solution being made by means of the colorimeter designed by Schreiner.

In 1908 and 1909, when the plats were planted to maize and oats, respectively, an unplanted space was left for twenty-five feet on the south end of each plat. This unplanted space was cultivated when the plats were in maize, receiving the same cultivation as did the planted part of the plat. When the plats were in oats the unplanted space was kept free from weeds by scraping with a hoe. Soil samples were taken from the planted and the unplanted sections of each plat on the same dates, which permits of a comparison of the effect of a certain soil treatment on the uncropped as well as on the cropped soil. It also serves to show the relation of the crop to the nitrates in the soil, which is a very important factor in their occurrence.

In Table 2 is given a statement of the nitrate content of the planted part of each plat on the dates sampled, during the three years. At the foot

TABLE 2. NITRATES IN SOIL IN PLATS 711 TO 732 AT CERTAIN PERIODS DURING THREE YEARS
(PARTS PER MILLION)

Plat	Timothy, 1907										Maize, 1908						Oats, 1909			
	April 23	May 3	May 14	May 22	May 24	June 6	June 13	June 20	July 24	August 14	May 19	June 22	July 6	July 27	August 10	September 17	April 22	June 24	July 12	August 7
711 c*	4	5	1	2	3	3	5	4	5	7	25	40	62	182	162	...	94	38	8	10
712	5	3	5	3	4	2	2	1	6	6	10	31	53	172	162	...	61	14	7	3
713	11	3	4	3	5	3	3	1	6	8	14	40	59	172	201	.	44	25	9	10
714 c	16	5	7	2	7	4	4	2	6	10	22	52	90	268	238	...	60	18	7	8
715	15	15	6	3	8	2	2	2	5	4	26	57	60	211	158	...	56	10	8	11
716	13	9	8	2	3	3	2	3	5	8	33	69	47	261	156	...	32	5	6	8
717 c	11	2	4	2	2	2	3	4	5	6	20	43	39	211	234	...	45	16	3	2
718	7	1	3	1	2	1	2	2	3	4	12	36	40	224	141	...	57	3	2	2
719	6	3	10	1	2	1	1	1	2	4	21	30	30	178	160	...	66	19	2	3
720 c	8	2	3	2	3	2	2	1	3	6	17	31	102	211	136	...	50	13	2	3
721	5	9	73	22	2	2	1	1	3	5	20	38	66	130	152	...	36	3	4	4
722	3	6	8	2	2	1	1	1	2	5	12	32	47	97	139	...	26	4	2	3
723 c	6	4	5	1	3	1	1	1	3	2	11	47	45	141	198	...	40	4	4	1
724	5	14	14	5	4	2	1	1	2	4	12	36	50	208	117	...	30	4	4	2
725	10	34	37	4	3	2	2	2	9	7	21	50	56	194	106	...	30	3	5	1
726 c	..	..	..	..	..	..	..	..	..	..	11	38	51	228	147	...	27	5	2	1
727	..	..	..	..	..	..	..	..	..	..	15	49	75	194	172	32	41	3	3	1
728	12	52	97	47	39	8	50	8	6	8	15	42	81	178	165	...	59	4	6	2
729 c	..	..	..	..	..	..	..	..	..	..	4	25	101	158	178	49	45	21	3	1
730 c	8	4	3	2	3	2	1	1	2	2	7	27	50	150	152	...	44	15	3	1
731	8	1	4	2	3	3	1	2	2	2	14	26	70	198	178	...	49	9	4	1
732	21	5	4	3	3	2	1	3	3	3	44	64	106	251	185	75	63	10	6	3
Average	9	9	16	6	5	2	4	2	4	5	18	41	63	192	165	52	48	11	5	4
Average for unfertilised plats	9	4	4	2	3	2	3	2	4	5	15	38	67	194	181	49	51	16	4	3

* c = Unfertilised plats.

of the table is the average for all plats on the dates analyzed, and below that is the average for all unfertilized and unmanured plats. The last, by eliminating the effect of nitrate fertilizers, is a better index to the normal course of nitrification than is the average of all the plats.

The timothy had been on the land for two years previous to 1907 and there was a good stand. Commercial fertilizers had been added to each of the previous crops, and farm manure once. For the crop of 1907, farm manure was applied as a top-dressing on October 2, 1906, to the plats designated in Table 1, and commercial fertilizers were applied on April 23 and 24, 1907. Soil samples were taken on April 23, immediately before the fertilizers were applied. The timothy was cut on July 23 and samples for nitrates were taken the next day. The maize was planted on May 29 and cut on September 24. No fertilizer nor manure was applied to either the maize or the oats. The oats were drilled in on April 23, the day following the first sampling for nitrates. They were harvested on August 6 and samples were taken on the following day.

Seasonal range of nitrates under timothy, maize, and oats

A striking feature of the nitrate content of the timothy plats is the uniformity and scarcity of nitrates throughout the growing season. In all except the nitrate-fertilized plats the nitrate content was higher in April and August than during the period of more active growth. The land had not been plowed for two years and was covered with a thick sod, neither of which conditions was favorable for nitrification. The seasonal range of nitrates under timothy resembled that under alfalfa in the experiments of King and Whitson and in those of Stewart and Greaves. During the first half of May, when growth first became active, there was a tendency for the nitrates to increase, as is shown by the analyses of May 3 and May 14; there was then a decrease during the remainder of May and during June, with a slight increase at the time of harvest which was continued in the middle of August when the aftermath was growing.

The timothy sod was plowed under in the autumn of 1907, but nitrification had not proceeded very rapidly up to the time of the first analyses on May 19, 1908. The most noticeable increase was between July 6 and July 27, 1908. At the latter date there was a very large accumulation of nitrates in the soil, probably the maximum of the season. This period of

active nitrification was also the time during which the maize was making its most active growth. The weather was warm and very favorable for the growth of maize, which was an unusually good crop this year. It is a striking fact that in spite of the pronounced growth of the maize at this time the nitrates increased at a rate which gave no appearance of their being used by the crop. The nitrate content under the crop and on the unplanted soil is shown graphically in Diagram I.

Between July 28 and August 10 there was a perceptible decline in the nitrate content, and between August 10 and September 17 this decline was very marked. It is strange that the diminution in nitrates should take place after that period of growth during which the maize plant has been shown to absorb fully one half of the nitrogen that it utilizes.

The analyses of April 22, 1909, which were made before the oats were planted, show a much higher nitrate content in the soil in the spring following maize than in that following timothy, although the analyses were made nearly a month earlier in 1909 than in 1908. Between April 22 and June 24 there was a considerable loss of nitrates, as is to be expected in view of the fact that the nitrogen absorption of the crop is greatest at that time. The lowest figures for nitrates, however, were on July 12 and August 7, although the crop could not have been making very heavy drafts on the former date and had been harvested before the latter date, and in the face of the fact that nitrification was at its maximum at those dates under the maize crop.

It would seem as if nitrate production is most pronounced during the active growth of the crop on the soil, and decreases with the less vigorous growth of the crop. The characteristic relations of the nitrate content of the soil under timothy, maize, and oats are shown in Diagram II.

Nitrates on the planted and the unplanted sections of the plats

As before stated, a part of each plat was left unplanted in 1908 and 1909, but was otherwise given, as closely as possible, the same treatment as was given to the planted section of the plat. When the planted section of the plat was in maize the unplanted section was given the same cultivation; when oats were growing on the planted section, the unplanted section was kept free from weeds by scraping the surface with a hoe. In 1908 unplanted sections were maintained on the north as well as on the south end of each plat for a distance of twenty-five feet from each end.

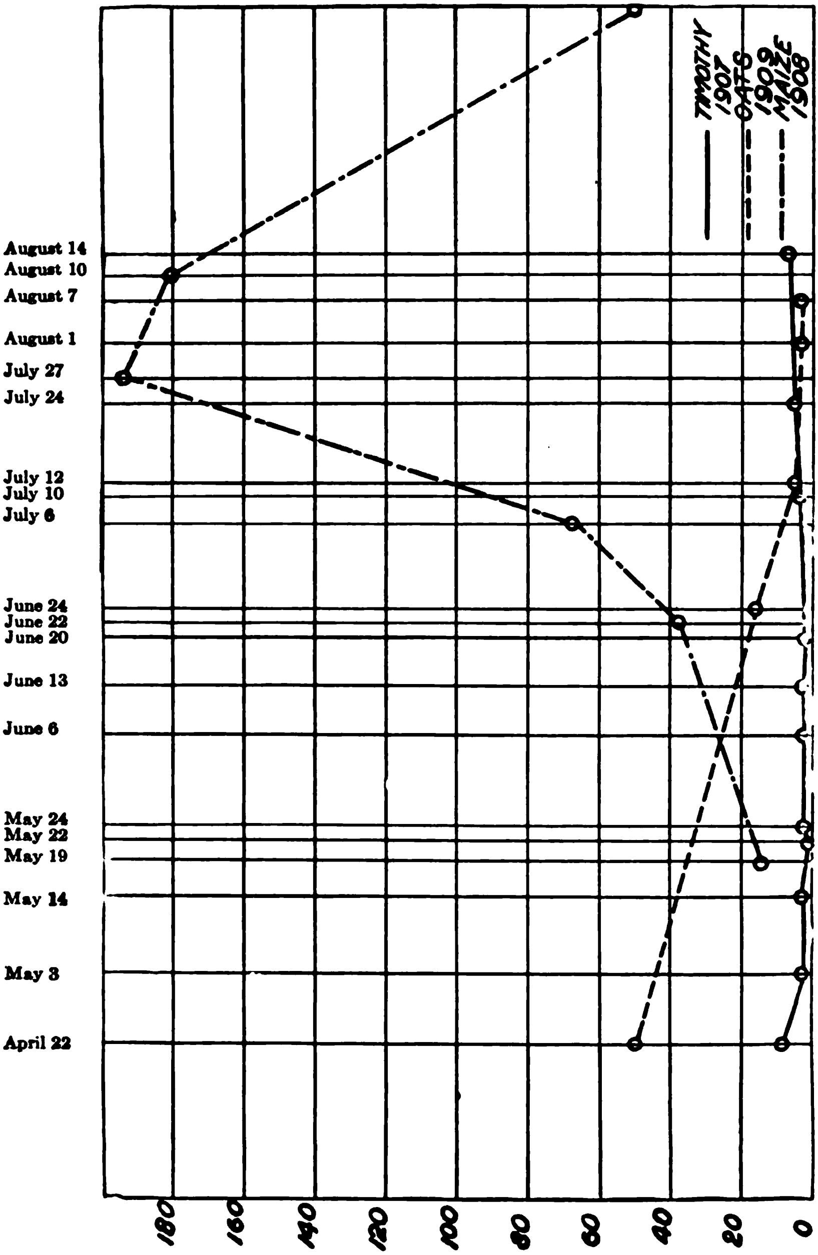

DIAGRAM II.—*Nitrates under timothy, maize, and oats, on unfertilized plats, during the seasons 1907, 1908, and 1909*

When the unplanted section at the north end was sampled, the north half of the planted area was sampled on the same date; and the same was done with the south part of the plat. The north and south halves were sampled alternately. In 1909 all samples were taken from the south halves of the plats, the unplanted and the planted parts corresponding exactly with those of the previous year. These are referred to as "north ends," "south ends," "north middles," and "south middles."

A comparison of the nitrate content of the unplanted and the planted sections of the same plat serves to indicate what has been the effect of the crop on the nitrate content of the soil. These figures for the years 1908 and 1909 are given in Table 3.

A striking feature of the nitrate content of the soil during the growth of maize is the close agreement between the nitrates in the planted and those in the unplanted sections of the plats. This is particularly noticeable in the analyses of July 27, previous to which the maize crop must have absorbed about one half of its nitrogen, judging by what is known of the life history of the plant. The previous heavy draft on soil nitrates is indicated by the analyses of June 22 and July 6, which show a lower nitrate content in the planted sections of the plats. The analyses of July 27 indicate either that the production of nitrates is proceeding much more rapidly in the cropped than in the uncropped soil, or that the maize crop is absorbing part of its nitrogen in some form other than as nitrates.

The analyses of August 10 show a decline of the nitrates on the planted areas, while on the unfertilized plats the nitrates still continue to increase on the unplanted spaces. From the standpoint of nitrogen utilization by the crop, the decline in nitrates at this late date is difficult to explain.

The analyses of April 22, 1909, made before the oats were planted, show a continuation of the more rapid decline on the maize land than on the uncropped spaces. The next analyses, June 24, show a marked decline in the nitrate content of the cropped sections of the plats, as do also those of July 12. By the latter date the nitrogen utilized by the oat crop has in large part been absorbed. The last analyses, however, on August 7, show a still greater decrease in the nitrate content, when a partial recovery might be expected and when the nitrate content of the uncropped soil has made a very great increase.

Comparing the two crops, the following facts are significant:

(1) When nitrification is at its maximum in the maize land the cropped

TABLE 3. NITRATES IN UNPLANTED SECTIONS (ENDS) AND PLANTED SECTIONS (MIDDLES) OF PLATS 711 TO 732 FOR TWO YEARS (PARTS PER MILLION)

Plat	Maize, 1908										Oats, 1909							
	May 19		June 22		July 6		July 27		August 10		April 22		June 24		July 12		August 7	
	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted
711c*	17	25	33	40	64	62	158	182	179	162	64	94	59	38	36	8	63	10
712	9	10	50	31	74	53	194	172	176	162	86	61	52	14	56	7	76	3
713	35	14	38	40	63	59	198	172	1[illegible]0	201	75	44	77	25	39	9	61	10
714c	15	22	54	52	63	90	221	268	188	238	86	60	35	18	127	7	56	8
715	29	26	44	57	50	60	221	211	164	158	86	56	93	10	129	8	83	11
716	30	33	45	69	42	47	255	261	205	156	114	32	49	5	70	6	76	8
717c	21	20	64	43	46	39	202	211	231	234	112	45	74	16	24	3	86	2
718	14	12	48	36	45	40	147	224	156	141	82	57	41	3	48	2	79	2
719	19	21	40	30	53	30	176	178	195	160	90	66	58	19	38	2	94	3
720c	19	17	43	31	70	102	156	211	185	136	81	50	52	13	35	2	77	3
721	27	20	54	38	98	66	194	130	198	152	77	36	14	3	12	4	119	4
722	25	12	31	32	70	47	194	97	158	139	63	26	70	4	36	2	127	3
723c	20	11	38	47	48	45	147	141	202	198	89	40	65	4	65	4	85	1
724	20	12	47	36	55	50	201	208	185	117	82	30	97	4	41	4	86	2
725	19	21	47	50	54	56	201	194	136	106	80	30	61	3	32	5	100	1
726c	17	11	47	38	40	51	194	228	136	147	50	27	48	5	61	2	66	1
727	17	15	40	49	34	75	174	194	178	172	71	41	25	3	60	3	65	1
728	22	15	56	42	104	81	168	178	154	165	85	59	32	4	68	6	135	2
729c	17	4	35	25	84	101	172	158	188	178	84	45	66	21	60	3	32	1
730c	7	7	43	27	104	50	195	150	221	152	56	44	50	15	46	3	51	1
731	36	14	82	26	47	70	238	198	227	178	106	49	48	9	65	4	67	1
732	45	44	79	64	104	106	304	251	147	185	122	63	58	10	79	6	114	3
Average	22	18	48	41	64	63	196	192	179	165	84	48	56	11	56	5	82	4
Average for unfertilized plats	17	15	45	38	65	67	181	194	191	181	78	51	56	16	57	4	64	3

*c = Unfertilized plats.

soil on the unfertilized plats contains more nitrates than does the uncropped soil.

(2) In oat land the nitrates are never so high in the cropped as in the uncropped soil.

(3) While the maximum nitrate content in the uncropped soil occurred at about the same dates in both years, that in the cropped soil varied with the crops.

(4) Under both crops the nitrate content was higher during the period when the crop was making its greatest draft on the soil nitrogen than in the later stages of growth, and this in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing.

These phenomena are explainable on the assumption that nitrification is stimulated by some processes connected with the active growth and absorbing functions of the plant roots, and is inhibited by the conditions accompanying the decreasing activities of the roots.

Aside from the influence of cultivation and nitrogen absorption, the reason for the large differences in the nitrates under these crops, as well as under the corn, potatoes, alfalfa, and oats grown by King and Whitson and by Stewart and Greaves, may be sought in the inherent differences between plants of different species as regards their stimulating or inhibiting effect on nitrate formation. Another factor that may be operative in determining the quantity of nitrates is the habit of the plant in respect to the form in which it absorbs nitrogen. It is conceivable that a plant may induce an active nitrification in the soil and yet absorb its nitrogen largely in the form of organic nitrogen.

The response of different plants to nitrogen in different forms indicates a difference in their abilities to utilize this material when in certain compounds. For instance, grass makes a quick and effective response to sodium nitrate, and the nitrate content of the soil, unless heavily dressed with nitrate fertilizer, is maintained at a very low point. Oats are less responsive to the nitrate fertilizer and do not reduce the nitrate content of the soil so low. Maize is but little affected by a nitrate fertilizer, while it is greatly benefited by fresh applications of farm manure. The nitrates, meanwhile, are present, apparently greatly in excess of the needs of the plant.

Relation of nitrates to soil moisture on the plats

Moisture determinations were made in all soil samples in which nitrates were determined; in addition, daily determinations of moisture were made in certain of the unfertilized plats during the summers of 1907 and 1908. It was thought that a record of the moisture content for a period preceding the nitrate determinations would show the relation between soil moisture and nitrate formation better than would a statement of the moisture content on the day on which nitrates were determined. The nitrate content and the average moisture content of the soil for the time intervening between the dates on which nitrates were determined are given in Table 4:

TABLE 4. AVERAGES OF DAILY DETERMINATIONS OF SOIL MOISTURE FOR THE PERIODS INTERVENING BETWEEN NITRATE DETERMINATIONS ON CROPPED SOIL

Timothy, 1907

	June 4 to 6		June 7 to 13		June 14 to 20		June 21 to July 24		July 25 to August 14	
Plat	711	720	711	720	711	720	711	720	711	720
Moisture (percentage)	22.8	26.3	23.4	26.3	23.8	27.0	21.7	25.1	17.9	21.2
Nitrates (parts per million)	3	2	5	2	4	1	5	3	7	6

Maize, 1908

	June 2 to 22		June 23 to July 6		July 7 to 27		July 28 to August 10	
Plat	711	720	711	720	711	720	711	720
Moisture (percentage)	22.7	22.6	21.1	21.5	24.0	25.3	22.1	22.8
Nitrates (parts per million)	40	31	62	102	182	211	162	136

In 1907 the moisture content was perceptibly lower and the nitrates were higher in plat 711 than in plat 720. In 1908 there was little difference in moisture in the two plats and no consistent difference in nitrates. In the latter part of July and the first part of August there was a decrease in moisture content in both plats each year; in 1907 this was accompanied by an increase in nitrates, while in 1908 a decrease in nitrates occurred. The drying out of the soil and consequent aeration does not appear to produce the same result in both cases, from which

it may be taken for granted that factors other than this are more important in nitrate formation. These figures are shown graphically in Diagram I.

Changes in soil moisture.— While the gradual changes in soil moisture content that have been examined do not appear to have constituted an important factor in promoting nitrate formation — at least not sufficient to prevail over other influencing conditions — the question arises whether the more frequent, although less marked, changes in moisture content due to the effect of transpiration from the plant in drying out the soil between rains would not cause greater nitrification on the planted than on the unplanted sections of the plats.

Analyses made in the course of the experiments here described give the daily moisture content of the planted sections on certain plats throughout the growing season. There were also moisture determinations made in each of the soil samples in which nitrates were determined, and these show to what extent the cropped soils dried out as compared with the uncropped soils. These data are given in tables 5 to 7:

TABLE 5. DAILY DETERMINATIONS OF MOISTURE IN SOIL UNDER TIMOTHY, 1907 (PERCENTAGE OF DRY SOIL)

Date	Plat 711	Plat 720	Plat 728	Plat 729
June				
6	23.3	27.3	25.0	27.5
7	30.7	32.6	29.9	34.5
8	25.0	27.5	24.5	28.0
11	21.2	23.4	20.7	23.4
12	20.9	23.7	....	23.4
13	19.3	24.5	20.6	23.3
14	19.0	23.0	18.9	21.7
15	18.9	23.4	17.6	22.8
17	23.0	24.6	20.6	25.4
18	14.9	18.6	16.6	18.9
19	30.3	32.6	31.0	32.4
20	37.2	40.0	37.1	41.8
21	35.1	38.8	36.8	40.2
22	21.0	24.0	22.2	25.6
24	18.7	22.1	19.3	22.8
25	18.6	22.4	17.3	23.6
26	22.4	24.6	21.9	27.3
27	22.8	20.3	18.6	23.8
28	20.6	....	19.6	25.3
29	19.4	21.7	17.7	22.2

TABLE 5 (*continued*)

Date	Plat 711	Plat 720	Plat 728	Plat 729
July				
1	26.4	29.7	28.2	31.0
2	27.5	31.0	29.3	29.5
3	25.6	28.2	27.5	27.5
5	24.2	27.0	25.3	27.0
6	22.5	25.4	24.0	25.7
8	20.0	23.7	23.3	23.8
9	19.6	23.6	21.6	23.7
10	18.7	20.7	19.3	21.5
11	19.4	20.6	20.9	19.7
12	25.9	31.2	29.9	30.2
13	26.4	29.2	28.2	29.2
15	23.3	26.1	23.7	26.6
16	20.9	23.4	23.3	24.0
17	20.0	24.2	23.7	25.1
18	21.9	25.1	23.7	26.4
19	18.9	22.1	19.7	22.1
20	18.7	22.6	20.3	22.1
22	19.0	20.9	20.4	24.2
23	15.6	20.9	19.0	22.5
24	16.0	20.1	18.7	21.2
26	16.8	20.0	19.6	21.7
27	16.6	19.3	16.0	20.7
29	15.6	19.7	17.5	21.3
30	14.9	18.7	16.8	20.0
31	14.5	21.2	17.6	19.6
August				
1	16.1	19.4	17.5	21.2
2	20.1	25.3	23.4	25.6
3	21.0	23.3	23.8	24.6
5	21.3	22.6	23.0	23.6
6	19.7	24.2	24.0	25.4
7	19.4	23.0	22.5	23.1
8	18.6	21.9	22.6	23.6
9	18.7	22.5	22.2	23.1
10	18.9	21.0	20.9	22.5
12	17.5	19.9	20.4	19.1
13	18.3	19.3	21.0	21.2
14	16.6	20.1	18.7	20.1
15	15.7	17.9	17.6	19.9
16	16.2	17.3	17.7	18.9
17	15.2	17.2	16.4	17.5
19	14.8	16.4	13.3	15.0
20	12.4	16.5	15.2	15.3

TABLE 6. DAILY DETERMINATIONS OF MOISTURE IN SOIL UNDER MAIZE, 1908
(PERCENTAGE OF DRY SOIL)

Date	Plat 711	Plat 720	Plat 728	Plat 729
June				
2	27.3	26.8	26.5	26.5
3	25.1	25.7	26.1	24.2
4	26.1	24.0	25.0	24.2
5	24.6	24.8	24.5	23.8
6	23.8	24.5	23.6	23.3
8	21.9	21.2	22.2	20.3
9	20.3	21.6	22.8	21.3
10	20.9	21.7	22.6	21.5
11	22.1	21.5	21.7	20.6
12	20.3	20.9	21.2	21.2
13	23.6	21.5	23.8	20.7
16	22.5	23.4	23.4	22.8
17	21.6	22.4	22.8	22.4
19	20.0	20.7	22.8	22.1
20	22.1	21.0	21.3	20.7
22	21.5	21.2	22.4	20.9
23	21.0	22.6	22.2	21.5
24	21.5	21.7	22.2	21.3
25	20.6	21.5	23.3	21.5
26	20.6	21.3	22.6	21.5
27	21.7	21.2	23.1	21.7
29	20.1	20.9	23.3	20.6
30	21.6	21.7	22.5	21.3
July				
1	21.5	21.2	22.6	20.7
2	20.7	21.5	....	....
3	21.3	21.2	22.4	20.0
7	20.9	21.0	21.5	20.9
8	23.1	23.4	24.6	23.1
9	22.5	22.6	23.8	22.1
11	24.0	21.7	21.7	21.3
13	26.8	26.7	27.5	26.1
15	23.1	25.1	24.2	25.0
16	21.0	23.6	23.7	23.3
18	22.5	24.2	24.2	22.8
20	21.7	22.8	23.8	22.2
21	21.7	22.6	23.7	22.6
22	26.4	29.7	28.7	28.0
23	26.4	28.8	27.8	27.2
24	24.2	26.8	26.5	25.6
25	28.8	30.3	31.9	27.8
27	26.8	28.5	26.7	26.7
28	24.8	27.0	27.2	27.5
29	23.6	25.1	25.1	23.0
30	23.4	24.2	24.2	22.8
31	22.4	22.5	24.3	22.1

TABLE 6 (*continued*)

Date	Plat 711	Plat 720	Plat 728	Plat 729
August				
3	19.3	19.9	21.0	19.6
4	18.7	20.3	21.3	19.1
5	23.0	21.9	23.4	23.0
6	22.1	23.1	24.6	23.1
8	24.5	25.6	25.7	25.9
11	21.0	20.7	23.1	23.0
12	20.9	21.0	23.0	21.3
13	18.2	19.0	21.6	20.9
14	21.3	22.2	23.1	22.2
18	22.5	22.4	24.5	24.2
19	21.2	22.4	24.6	21.7
20	21.6	21.7	23.0	21.7
21	20.0	21.0	21.9	21.7

TABLE 7. AVERAGE MOISTURE CONTENT FOR PLANTED AND BARE SECTIONS OF MAIZE PLATS ON DATES DESIGNATED (PERCENTAGE OF DRY SOIL)

Date	Plat 711		Plat 720		Plat 728		Plat 729	
	Un-planted	Planted	Un-planted	Planted	Un-planted	Planted	Un-planted	Planted
June								
3	27.0	25.1	......	......	......	......	......	......
4	......	......	23.3	24.0	......	......	......	......
5	......	......	......	......	25.0	24.5	......	......
6	......	......	......	......	......	......	22.6	23.3
9	21.6	20.3	......	......	......	......	......	......
10	......	......	21.0	21.7	......	......	......	......
11	......	......	......	......	23.1	21.7	......	......
12	......	......	......	......	......	......	21.5	21.2
16	23.6	22.5	......	......	......	......	......	......
17	......	......	21.9	22.4	......	......	......	......
19	......	......	......	......	24.5	22.8	......	......
20	......	......	......	......	......	......	21.0	20.7
24	22.5	21.5	......	......	......	......	......	......
25	......	......	21.5	21.5	......	......	......	......
26	......	......	......	......	23.1	22.6	......	......
27	......	......	......	......	......	......	22.1	21.7
30	21.7	21.6	......	......	......	......	......	......
July								
1	......	......	20.6	21.2	......	......	......	......
2	......	......	......	......	23.3	......	......	......
3	......	......	......	......	......	......	21.3	20.0
8	24.6	23.1	......	......	......	......	......	......

TABLE 7 (*continued*)

Date	Plat 711		Plat 720		Plat 728		Plat 729	
	Un-planted	Planted	Un-planted	Planted	Un-planted	Planted	Un-planted	Planted
July (*continued*)								
9	......	......	23.4	22.6	......	......	......	......
11	......	......	......	......	23.4	21.7	......	......
13	......	......	......	......	......	......	28.2	26.1
16	24.5	21.0	......	......	......	......	......	......
18	......	......	23.4	24.2	......	......	......	......
20	......	......	......	......	25.0	23.8	......	......
21	......	......	......	......	......	......	23.0	22.6
23	28.0	26.4	......	......	......	......	......	......
24	......	......	26.4	26.8	......	......	......	......
25	......	......	......	......	31.7	31.9	......	......
27	......	......	......	......	......	......	27.2	26.7
29	24.5	23.6	......	......	......	......	......	......
30	......	......	22.6	24.2	......	......	......	......
31	......	......	......	......	24.6	24.3	......	......
August								
3	......	......	......	......	......	......	20.0	19.6
5	21.0	23.0	......	......	......	......	......	......
6	......	......	21.9	23.1	......	......	......	......
8	......	......	26.7	25.6	......	......	......	......
11	......	......	......	......	23.8	23.1	......	......
12	......	......	......	......	......	......	21.7	21.3
14	23.4	21.3	......	......	......	......	......	......
18	......	......	23.3	22.4	......	......	......	......
19	......	......	......	......	24.0	24.6	......	......
20	......	......	......	......	......	......	22.1	21.7

It is seen from these tables that, while there is considerable range in the maximum and minimum moisture contents of these plats, the changes are not rapid; at least, the drying-out process is slow, and it is the drying that causes aeration in soil. Furthermore, it is quite apparent that on the maize soil, in which nitrification is most active, the changes in the moisture content of the cropped soil do not differ greatly from those on the uncropped soil on the same dates. It is also very evident that the changes in the moisture content continue throughout the summer, and should therefore induce nitrate formation during the ripening stage of the crop growth as well as in the early stages; while Table 2 shows that nitrate production is greater on the planted soil only during the earlier stages of growth.

In diagrams I (page 20), V (page 42), VI and VII (page 52), XVI (page 64), XXVI (page 94), and XXVII (page 95) the moisture and nitrate contents of the soils for the years 1908, 1910, 1911, and 1912 are shown graphically. In these diagrams both moisture and nitrates in the planted and the unplanted sections of the plats are shown for one to three crops each year. The diagrams serve to bring out plainly any related changes that may occur in these two constituents of the soil.

These diagrams sometimes show an increase of nitrates accompanying or following a rise in moisture content, and sometimes a decrease, in both the planted and the unplanted soil. A decrease in nitrates may be due to leaching after a very heavy rainfall. This is strikingly shown in the analyses following the heavy rain of September 1, 1912. In most of the years included in these records there was a dry period during the latter part of June or in July, and at this time the soil moisture usually reached its minimum. As the soil moisture increased in August there was generally an increase in nitrates in the unplanted soil; in the planted soil, however, there was much less regularity in this relation and it varied with the kind of plant grown on the soil. The nitrates in oat soil, for instance, were usually not influenced by an increase in moisture content, while under maize they sometimes responded to such an increase.

Some relations between soil temperature and nitrate formation

Records were kept of the soil temperatures taken daily at 4.30 p. m. during the growing seasons of 1907 and 1908, at a depth of six inches on certain unfertilized plats. In Table 8 are given the average temperatures for the periods between the dates on which nitrates were determined, also the nitrate content at the end of the period:

TABLE 8. AVERAGES OF DAILY SOIL TEMPERATURES AT DEPTH OF SIX INCHES FOR THE PERIODS INTERVENING BETWEEN NITRATE DETERMINATIONS ON CROPPED SOIL

Timothy, 1907	June 7 to 13		June 14 to 20		June 21 to July 24	
Plat	711	720	711	720	711	720
Temperature (Fahrenheit)	60.0°	60.5°	65.3°	66.5°	68.1°	69.2°
Nitrates (parts per million)	5	2	4	1	5	3

TABLE 8 (*continued*)

Maize, 1908	June 2 to 22		June 23 to July 6		July 7 to 27		July 28 to August 10	
Plat	711	720	711	720	711	720	711	720
Temperature (Fahrenheit)	66.8°	65.9°	69.2°	69.8°	69.4°	69.8°	72.2°	71.1°
Nitrates (parts per million)	40	31	62	102	182	211	162	136

In the year 1907 the nitrates were fairly constant in amount throughout the season in these plats, in spite of changes in soil temperature. This is probably because of the heavy draft of the timothy crop on the soil nitrates. In 1908 the nitrates increase in quantity up to July 27, although the average temperature from July 6 to that date is practically constant. From July 28 to August 10 there is a marked rise in temperature in both plats, but it is accompanied by a decrease in nitrates. The temperatures reached in these plats are not high enough to have any depressing effect on nitrification, as has been demonstrated by many experiments.

In diagrams I (page 20), V (page 42), VI (page 52), and XVI (page 64) are shown the daily mean air temperatures, and in some seasons the daily soil temperatures, and the nitrate contents of the soil for the years 1908, 1910, 1911, and 1912. In the unplanted soil the nitrates usually increased in the spring with the rise in temperature. This continued until July, after which there was apparently little relation between temperature and nitrate content until late autumn. For instance, in 1911 and 1912 there was a decrease in the temperatures from the first half of July to the end of August, while the nitrate content of the unplanted soil increased steadily during that period. The planted soil cannot be said to show any consistent relation between temperature and nitrate content during midsummer.

Experiments with maize in which other plants were sown

In 1907 and 1908 certain plats were planted to maize, between the rows of which the seeds of other plants were sown broadcast. A part of each plat was not planted to maize, but when the other seed was sown between

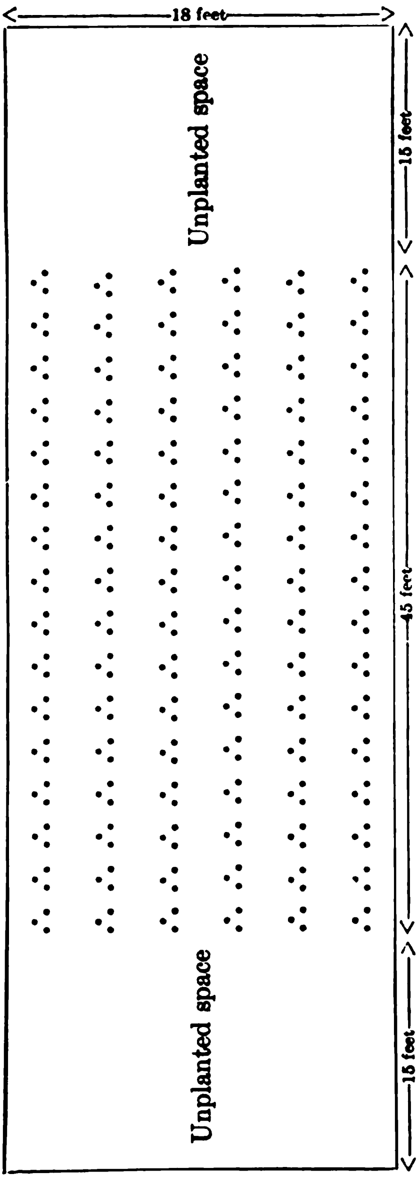

DIAGRAM III.—*Arrangement of maize plats in 1907*

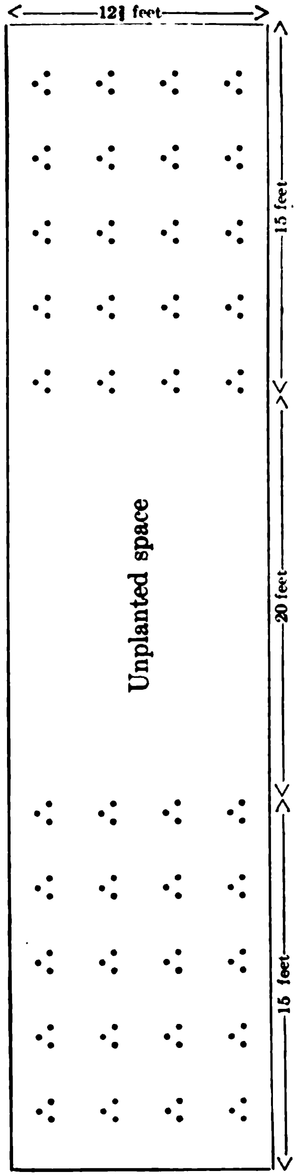

DIAGRAM IV.—*Arrangement of maize plats in 1908*

the maize rows it was sown also on the part of the plat on which no maize was planted. In 1907 maize was in the center section of the plat and the sections not planted to maize were on the two ends. In 1908 maize was on the end sections and the soil in the middle was left unplanted. These plats were not on the same soil in 1908 as in 1907. In 1907 the plats were on a sandy soil, while in 1908 they were on the clay loam on which the experiments already discussed were conducted. The arrangements of these plats are shown in diagrams III and IV.

The soil samples were taken with a soil auger to the depth of seven inches. Each sample in 1907 was obtained in the following manner: six borings were taken, carefully mixed on a tablet in the field, placed in a tightly closed jar, and carried to the laboratory for moisture and nitrate determinations. In 1908 four borings were made in each end of the plat, the eight borings from the two ends of the same plat were mixed, and a part was taken as a sample. Samples from the middles were composed of six borings.

Experiments with maize, millet, and soy beans in 1907

Maize was planted in hills three feet apart each way. Five kernels were planted in each hill and these were later thinned to three stalks in a hill. Millet was sown on the ends of certain plats and soy beans on the ends of other plats. These were sown when the maize was cultivated on the dates stated in Table 10. Every third plat was a check plat and was planted only to maize, the weeds in these check plats being kept down by cultivation. The unplanted ends received the same cultivation as the remainder of the plat. Nitrates on the planted and the unplanted sections are given in Table 9.

The analyses were all made late in the growing season, when the growth of maize had reduced the nitrate content in the planted sections below that in the bare sections. The nitrate content of the unplanted soil is fairly constant until late in the season, when, conditions in September evidently being favorable for the process of nitrification, the average for September 16 shows that the nitrates in the unplanted soil have more than doubled since the analyses of August 25. This may have been due to the abundant rainfall during the early part of September, there having been 2.53 inches between September 1 and September 16, while

TABLE 9. NITRATES IN MAIZE AND IN UNPLANTED SECTIONS OF PLATS 1, 4, 7, 10, 13, IN 1907 (PARTS PER MILLION)

Plat	August 5		August 19		August 25		September 16	
	Maize	Un-planted	Maize	Un-planted	Maize	Un-planted	Maize	Un-planted
1	52	90	19	72	15	70	13	130
4	49	111	16	84	16	92	15	208
7	63	96	9	54	10	80	36	143
10	24	73	14	50	31	69	31	165
13	18	56	30	79	41	69	55	183
Average	41	85	18	68	23	76	30	166

there was only .73 inch between August 1 and August 31. On September 9 there was a rainfall of 1.06 inch; however, although this soil is very sandy, there could have been little leaching of nitrates judging from the nitrate content on September 16.

Notwithstanding the very favorable conditions for nitrification and the large nitrate content of the unplanted soil, there is practically no increase of nitrates in the planted soil. This is a striking exemplification of the hypothesis previously advanced, namely, that at least certain plants in some way inhibit the formation of nitrates in the soil during the later stages of plant growth. It is certainly impossible to account for the failure of the nitrates on the cropped soil to increase by supposing that they were leached out of the topsoil, as they would not have remained practically constant while the nitrates in the uncropped soil doubled.

The plats sown to millet and to soy beans afford an opportunity to study the effect of these crops on the nitrate content of the soil by comparing the ends of the plats which, as already explained, were sown to either millet or soy beans alone, with the unplanted ends of contiguous plats. Such a comparison is made in Table 10.

There seems to be little tendency for the nitrates to increase under either of these crops during the early stages of growth; yet those crops that were planted after the first analysis was made, thus permitting frequent observation, display something of this tendency. Thus, on

TABLE 10. NITRATES IN MILLET OR SOY BEANS ALONE AND IN UNPLANTED SECTIONS OF ADJACENT PLATS IN 1907 (PARTS PER MILLION)

Date	Plat 5 Millet sown June 18	Plat 4 Un-planted	Plat 6 Millet sown July 24	Plat 7 Un-planted	Plat 8 Millet sown August 6	Plat 10 Un-planted	Plat 9 Soy beans sown July 5	Plat 11 Soy beans sown July 24	Plat 13 Un-planted
July 9	85	98	79	90	100	54	99	53	57
July 15	73	88	78	82	62	34	60	26	30
July 22	30	110	114	78	101	84	76	74	82
July 29	7	92	73	68	80	52	19	54	60
August 5	2	111	135	96	135	73	9	57	56
August 12	6	96	82	84	111	62	4	75	79
August 19	1	84	60	54	84	50	3	55	79
August 25	2	92	41	80	94	69	2	55	69
September 2	1	96	25	74	66	88	2	52	90
September 16	2	208	6	143	45	165	10	145	183
	Yield per acre		Yield per acre		Yield per acre		Yield per acre	Yield per acre	
	4,999 pounds dry matter		2,026 pounds dry matter		772 pounds dry matter		3,700 pounds dry matter	894 pounds dry matter	

comparing the nitrates under millet sown on July 24 on plat 6 with those in the check plats 4 and 7, it is seen that the first determination of nitrates after the millet was up showed an increase in all three plats; but the increase under the millet was 62 parts per million, while that under the checks was 19 and 28 parts per million, respectively. The millet sown on August 6 did not make much growth. The decrease in nitrates between the analyses of August 12 and August 19 under the millet on plat 8 was 27 parts per million as against 30 and 12 parts per million on plats 7 and 10, respectively. Plat 9, on which soy beans were sown on July 5, shows about the same nitrate content at each analysis up to July 22 as does its check, plat 7; and plat 11, which was sown to soy beans on July 24, continues about the same as its check until August 19. Neither crop can be said to have been associated with marked increase in nitrates at any stage of its growth, although the nitrate content of the soil under them does not show, in early growth, the decrease that would be expected.

There is the same tendency for nitrates to continue at a low figure throughout the later part of the season under millet, as has already been noted under maize and oats. Although plat 4 shows an increase in nitrates from 96 parts per million on September 2 to 208 parts per million on September 16, plat 5 shows practically no gain, notwithstanding

the fact that the absorption of nitrogen by the millet crop had practically ceased at that time. The millet sowings of July 24 and August 6 show the same phenomenon.

Soy beans do not exhibit this property to the same degree. Between the dates mentioned there was a slight increase in nitrates under the sowing of July 5, and a marked increase under the sowing of July 24.

Experiments with maize, millet, and weeds in 1908

The plan of experiments in 1908 was primarily the same as that in 1907; soy beans were not used, however, and there was a difference in the arrangement of the planted and the unplanted sections of the plats and in the character of the soil, all of which have before been noted. Analyses were made only on July 22 and August 31. In Table 11 is given a comparison of the amount of nitrates in the planted and the unplanted sections of the check plats, all of which received the same treatment:

TABLE 11. NITRATES IN MAIZE AND IN UNPLANTED SECTIONS ON PLATS 1, 4, 7, 10, 19, 22, 25, IN 1908 (PARTS PER MILLION)

Plat	July 22		August 31	
	Maize	Unplanted	Maize	Unplanted
1	85	66	99	79
4	66	60	90	82
7	78	64	107	79
10	75	69	105	48
19	172	102	112	82
22	140	143	99	75
25	140	101	126	75
Average	108	86	105	74

The higher nitrate content of the planted soil on July 22 is in line with previous results; a similar relation on August 31 is not, however, as the nitrate content under maize is usually low at that time. The growth of maize was very poor on these plats, the plants growing only three or four feet high and producing only about one third of a crop of fodder. There was consequently a very small absorption of nitrogen as compared with a normal crop.

Millet was sown in the maize and in the middles of certain plats, as in 1907, but was not sown on different dates. A miscellaneous assortment of weed seeds was sown on the ends and on the middles of other plats. In Table 12 is shown the nitrate content of the soil under maize and millet mixed, under maize and weeds mixed, under millet alone, and under weeds alone:

TABLE 12. NITRATES IN SECTIONS OF PLATS IN MAIZE AND MILLET, IN MAIZE AND WEEDS, IN MILLET ALONE, AND IN WEEDS ALONE, 1908 (PARTS PER MILLION)

Plat	July 22		August 31	
	Maize and millet	Millet	Maize and millet	Millet
6	77	44	10	4
21	139	96	45	6
	Maize and weeds	Weeds	Maize and weeds	Weeds
5	84	56	15	8

The yields of maize were extremely poor on these plats. This is an interesting condition, as it gives in some cases about the same yield of maize and millet combined as of millet alone, and the same yield of maize and weeds combined as of weeds alone. This is brought out in Table 13:

TABLE 13. YIELDS ON SECTIONS OF PLATS PLANTED TO MAIZE AND MILLET, TO MAIZE AND WEEDS, TO MILLET ALONE, AND TO WEEDS ALONE (IN POUNDS)

Plat	Crop on section	Yield of maize	Yield of other crop	Total yield on section	Yield on sections calculated to same area
6	Maize and millet	4	50	54	36
	Millet	....	42	42	42
21	Maize and millet	3	44	47	31
	Millet	....	34	34	34
5	Maize and weeds	6	23	29	19
	Weeds	....	18	18	18

The nitrates were uniformly higher in the soil planted to the mixture than in the soil planted to a single crop, in spite of the fact that the draft on the available nitrogen must have been nearly the same on both sections. If it is true that the early stages of plant growth favor nitrification in the soil, and that, as indicated by results already presented, maize is much more effective in this respect than is millet, the higher nitrate content under the mixture of maize and millet than under millet alone is readily accounted for.

This experiment, moreover, eliminates the factor of cultivation, to which the higher nitrate content under maize has usually been ascribed. With the maize plats receiving no more cultivation than the millet plats and producing practically the same total quantity of dry matter, the higher nitrate content of the maize soil must be due to some factor other than cultivation. This again suggests the alternative of a beneficial influence on nitrate production, or the utilization by the maize plant of nitrogen in some other form than that of nitrates.

The excessive supply of nitrates in soil planted to maize

Another significant fact brought out by a study of the nitrates under maize is the great excess of nitrates over the apparent needs of the plant during the first half of the growing season. Under oats and millet there appears to be an increase of nitrates during the very early stages of growth, but this quickly disappears as the growth of the plant proceeds. Under grass there is little or no accumulation of nitrates at any stage during the growth of the first crop of the year. Under maize, however, the nitrates accumulate in apparently excessive quantity up to the middle of the growing season, although during this time the crop is growing actively and absorbing large quantities of nitrogen.

In order to obtain some knowledge of the nitrogen absorption during that period of the growth of the maize plant when nitrates were accumulating in the soil, as compared with its later growth, the figures obtained by Roberts and Wing (1888 and 1890) with the same variety of maize (Pride of the North), and in the same field as that in which the experiments with maize and millet were conducted in 1907, may be quoted. In their experiment of 1888 the maize was planted on May 7 and was out of danger of injury from frosts by September 10. Parts of the crop were cut on different dates, weighed, and analyzed. From the weights

and the protein nitrogen content of the crop on certain dates, the amounts of nitrogen removed by the plants on these dates may be calculated; and on the basis of weights and analysis at final harvest, the proportion of the total nitrogen acquired by the plant may be deduced for any of the dates on which the cuttings were made. Estimated in this way the maize plants had absorbed 43 per cent of their nitrogen on July 24 and 63 per cent on August 8. In 1889 the maize was planted on May 12 and was mature by September 24. It had acquired 53 per cent of its total nitrogen on August 2, 50 per cent on August 17, and 67 per cent on August 31. The figures for 1889 are somewhat contradictory, as the proportion of nitrogen taken up on August 17 was less than that on August 2. The figures, as a whole, indicate that at least 50 per cent of the nitrogen utilized by Pride of the North maize in this locality in an average year is absorbed by the end of July. Referring to Table 3, it will be seen that on July 27 the nitrate content of the soil under maize on the unfertilized plats was 194 parts per million, while that on the cultivated soil on which no plants grew was 181 parts per million. Even as late as August 10 the nitrate content under the maize on these plats was 181 parts per million, and on the unplanted soil it was 191 parts per million. It is to be expected that there would be a large accumulation of nitrates in the cultivated and uncropped soil, but why this should be true of the soil carrying a heavy crop of maize, practically one half of the nitrogen of which had been absorbed, it is difficult to understand. The formation of nitrates during this period must have proceeded with tremendous activity if nitrates were the source of nitrogen supply for the crop.

Some conditions indicate that maize, at least during part of its period of growth, utilizes nitrogen rather largely in forms other than as nitrates. Ammonification apparently never proceeds more rapidly than nitrification in this soil, which would bar that form of nitrogen as a very considerable source of supply. Organic nitrogen in some of its soluble forms is the only remaining alternative. The great benefit derived by maize from the application of farm manure suggests the possible use of nitrogen in this form.

During the later growth of the maize plant there is a large falling-off in the nitrate content of the soil under the plants as compared with that in the unplanted soil. This indicates either that nitrates are absorbed by maize in large quantities during the period of growth in which it is

obtaining the second half of its nitrogen supply, or that nitrate formation is depressed at that time.

Nitrates in soil planted to maize, potatoes, and oats

Experiments in 1910

During the growing season of 1910, determinations of nitrates were made under maize, potatoes, and oats. These were from four plats planted to each crop, of which two plats were limed and two were unlimed. An unplanted strip ran through the center of each plat. Soil samples were taken on the planted and on the unplanted sections of each plat. The sections are designated as "north ends," "middles," and "south ends." The north ends and the south ends were both planted; the middles grew no crop, but were given the same soil treatment as the remainder of the plat. This consisted in cultivation on the maize and potato plats and in scraping the surface on the oat plats. Soil samples were taken to a depth of four feet on the north ends and on the middles, but to a depth of only one foot on the south ends, except on May 12, when composite samples from the north ends and the south ends were analyzed.

The soil on which these plats were located was a heavy clay loam in the same field as that in which most of these experiments have been conducted. This particular piece of land was not uniform as regards either production of crops or nitrates. Fortunately each crop was grown on four separate plats, and in spite of irregularities in single plats the average of the four plats in each crop gives fairly concordant results.

The weather during the growing season of 1910 was drier than normal and the early part of the season was unusually cool. The yield of oats and of potatoes was about the average, but the maize crop was very poor. The small maize crop was due to the soil rather than to the weather, as no manure had been applied and this soil does not produce good yields of maize unless it is well manured. It will be noticed from Table 14 that the nitrates under maize reached over a hundred parts per million in the surface foot of soil; yet, in spite of this large quantity of soluble nitrogen, the crop was very poor. Potatoes and oats made a much better growth and reduced the nitrates considerably lower. This is another example of the slight response of maize to nitrates on this soil.

Planting was done on the following dates: oats (White Russian) on April 28; potatoes (Enterprise) on May 16; maize (Pride of the North)

on May 21. The oats were harvested on August 7 and the maize and potatoes on October 20.

A statement of the average nitrate content of the surface foot of soil on the cropped and the uncropped sections of the four plats planted to each crop is given in Table 14. For the cropped sections the averages include both the cropped ends of the plats. Moisture contents for the same plats and dates are given also.

TABLE 14. AVERAGE NITRATE CONTENT AND AVERAGE MOISTURE IN THE SURFACE FOOT OF SOIL ON THE FOUR PLATS PLANTED TO EACH CROP, ON DATES ANALYZED

Nitrate content (parts per million)

Plat	Crop	May 12		June 1		July 28		August 17		September 9		October 17	
		Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted
3612, 3613, 3622, 3623	Maize	66	57	98	62	168	92	179	167	247	273	244	167
3614, 3615, 3624, 3625	Potatoes	95	34	122	58	127	145	139	135	99	130	43	145
3616, 3617, 3626, 3627	Oats	97	49	125	88	75	84	82	154	67	170	97	211

Moisture (percentage of dry soil)

Plat	Crop	May 12		June 1		July 28		August 17		September 9		October 17	
		Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted
3612, 3613, 3622, 3623	Maize	20.9	20.0	25.6	24.5	16.0	16.7	22.1	23.0	22.1	23.0	16.5	17.4
3614, 3615, 3624, 3625	Potatoes	21.1	20.7	25.7	24.2	14.5	16.1	20.3	19.6	20.3	19.5	19.0	17.2
3616, 3617, 3626, 3627	Oats	22.9	21.6	25.7	25.2	9.2	14.9	18.0	18.2	18.0	18.2	16.2	16.5

An examination of this table shows, so far as the maize crop is concerned, the characteristically higher nitrate content in the planted than

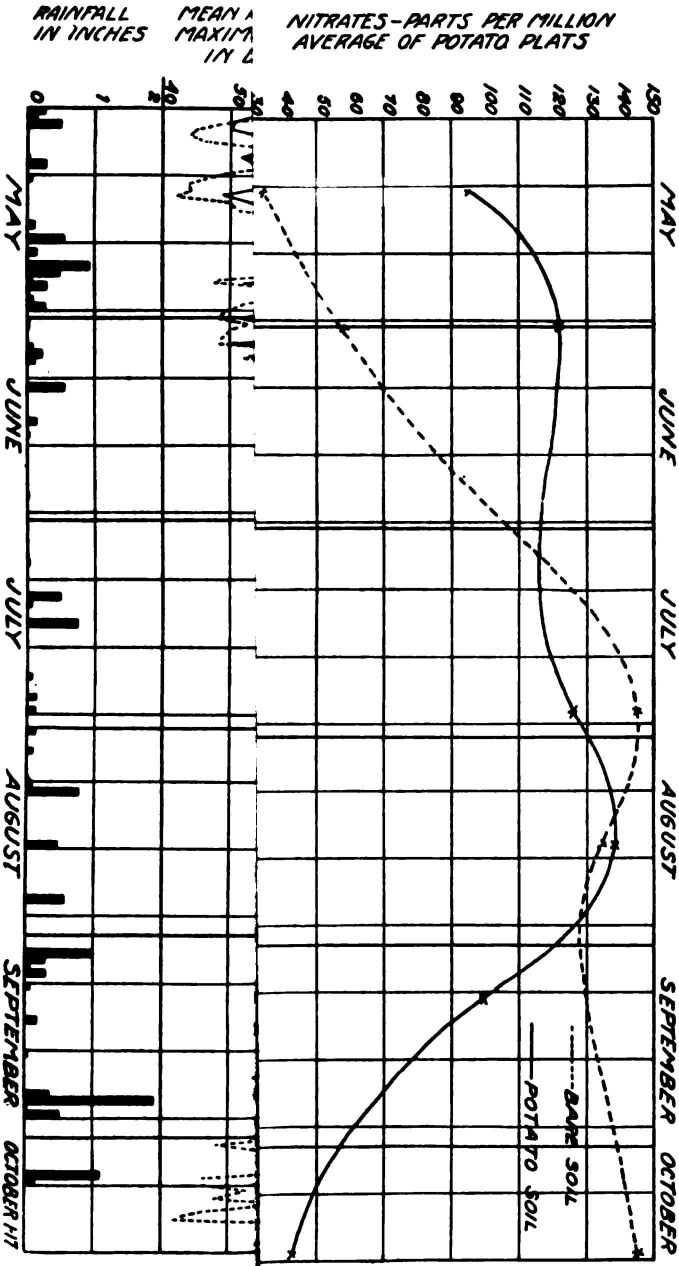

DIAGRAM V.—*Nitrates* *ure and daily rainfall for the growing season*

in the unplanted soil during the latter part of July. The nitrate content of the planted soil was slightly higher than that of the unplanted soil before the crop was seeded, and nitrates continued to develop more rapidly under the maize up to the latter part of July. From that time until the maize was mature in September the nitrates under the crop decreased as compared with those in the unplanted soil, in the usual manner; the analysis of October 17, however, shows a greater relative increase in the planted soil, which is contrary to the hypothesis that has been advanced. It is possible that the very feeble growth of the crop may account for this.

Potatoes, which yielded a normal crop, gave results similar to those obtained from normal yields of maize. The difference in the nitrate content of the potato plats and of the contiguous maize plats on October 17 is very marked. Although the vines were dead at this time, the nitrates were lower under the plants than at any period during their growth, while nitrate formation had again gone forward in the unplanted soil.

Nitrates under the planted and the unplanted sections of the oat plats were of the same relation as in previous years. On the planted sections the nitrates continued to decrease after harvest, as shown by the analysis of September 9 — one month after harvest. A slight increase is shown by the analysis of October 17, but it will be noted that, while nitrates in the planted soil increased 15 parts per million between harvest and October 17, the unplanted soil shows an increase of 57 parts per million in its nitrate content. The course of the nitrates in the planted and the unplanted soil is shown in Diagram V.

Nitrates at different depths.— In order to ascertain what effect the upward and downward movement of nitrates may have on the apparent connection between the plant and the nitrate content of the surface soil, samples were taken on the north ends and on the middles of each plat to a depth of four feet, each foot being analyzed separately. The results of these analyses are shown in Table 15.

The analyses show that nitrates are found to a depth of four feet, but that the changes in nitrate content of the soil are not great beneath the first foot. When changes occur in the second foot, they usually accompany corresponding changes in the surface foot. An increase in the nitrates in the surface foot is seldom accompanied by a decrease in the second

TABLE 15. NITRATES IN EACH FOOT OF THE UPPER FOUR FEET OF SOIL (PARTS PER MILLION)

Crop	Depth (feet)	May 12		July 28		August 17		September 9		October 17	
		Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted	Unplanted	Planted
Maize	1	66	57	174	92	201	167	236	273	309	167
Maize	2	34	25	55	47	49	43	79	100	64	57
Maize	3	25	17	41	26	44	34	47	56	43	33
Maize	4	21	15	44	31	42	24	45	72	50	40
Total	....	146	114	314	196	336	268	407	501	466	297
Potatoes	1	95	34	155	145	164	135	110	130	35	145
Potatoes	2	39	19	50	44	63	49	52	60	29	42
Potatoes	3	30	20	37	35	44	38	28	38	25	38
Potatoes	4	31	18	35	31	42	36	28	29	27	37
Total	....	195	91	277	255	313	258	218	257	116	262
Oats	1	97	49	106	84	96	154	84	170	153	211
Oats	2	32	27	37	33	39	48	28	47	51	53
Oats	3	16	12	21	23	28	35	20	46	27	28
Oats	4	31	22	22	23	25	30	22	40	28	33
Total	....	176	110	186	163	188	267	154	303	259	325

foot, as would be the case if the augmented nitrate content of the surface foot was due to an upward movement of the nitrates. On the other hand, the surface and second feet usually increase or decrease in nitrates on the same dates, indicating a downward movement of the nitrates. It would appear from these figures that in the main the nitrate content of the surface foot is determined by the rate of nitrification and by the removal of the nitrates, by various means, from that layer of soil.

The average nitrate content of the maize, potato, and oat plats for the season bears no definite relation to the quantities of nitrogen removed in the crops. In Table 16 the yield of dry matter and of nitrogen in the crops and the average nitrate content of the soil are given.

As usual, the nitrate content is highest under maize, next under potatoes, and lowest under oats. As the nitrogen removed from the soil by the maize crop was less than that absorbed by either of the others, the higher nitrate content of the soil might be considered to be due to that; however, as the potatoes removed more nitrogen than the oats and yet the nitrate content under the potatoes is higher than that under the

TABLE 16. YIELD OF DRY MATTER AND OF NITROGEN IN CROPS, AND AVERAGE NITRATE CONTENT OF SOIL, 1910

Crop	Yield of dry matter (pounds)	Yield of nitrogen (pounds)	Nitrates in first foot of dry soil (parts per million)		Nitrates in planted soil when nitrates in unplanted soil are taken as 100	
			Planted	Unplanted	Planted	Unplanted
Maize	221	3	167	136	123	100
Potatoes	1,910	43	104	108	96	100
Oats	1,670	29	90	126	71	100

oats, the relationship does not hold. Instead, the characteristic relation of the kind of plant to the nitrate content of the soil is again repeated, and this appears to hold, to a large extent, regardless of the relative quantities of nitrogen removed by the crops.

Experiments in 1911

The plat experiments were continued in somewhat the same manner in 1911, but none of the plats were limed. As before, each crop was grown on four separate plats, thus removing to a great extent the error due to local differences in nitrate formation. Another feature introduced in 1911 was the different methods of treatment of maize. Certain plats were mulched with straw, others were scraped with a hoe in order to keep them free from weeds without stirring the soil, and still others received the usual cultivation. The maize was treated also in the following two ways: (1) The crop was harvested on the first of August, the planting having been done at the usual time; the object of the early harvest was to ascertain the effect of the immature plants on the nitrates after the crop was removed. (2) The maize was planted about a month later than on the plats just mentioned and was harvested on August 1. This gave a very immature crop (about eighteen inches high) at harvest

Potatoes were grown as in 1910.

Oats were treated in two ways: (1) on one set of oat plats the land was plowed immediately after harvest and maize was planted; (2) on another set of plats maize was not planted after removing the oats, but the land was plowed and given the same cultivation as was given the maize. The object in giving this treatment after harvesting the oats

was to see whether the maize would cause the nitrates to increase in the oat soil and thus overcome the depressing effect of the oats.

The plat treatments may be briefly stated as follows:

Plat	Crop and soil treatment
2201, 2209, 2401, 2409	Maize planted May 20. Mulched
2202, 2210, 2402, 2410	Maize planted May 20. Scraped
2203, 2211, 2403, 2411	Maize planted May 20. Cultivated all summer
2204, 2212, 2404, 2412	Maize harvested August 1. Cultivated all summer
2205, 2213, 2405, 2413	Maize planted June 26, harvested August 1. Cultivated all summer
2206, 2214, 2406, 2414	Potatoes planted May 19. Cultivated all summer
2207, 2215, 2407, 2415	Oats planted May 9. Cultivated after harvest
2208, 2216, 2408, 2416	Oats planted May 9, followed by maize. Cultivated after oat harvest

The temperature during the growing season was nearly normal. There was a deficiency of rainfall, especially during August, at which time the maize suffered from lack of moisture. Oats made a normal growth, as did also potatoes. A killing frost on September 14 stopped growth of all crops on that date.

The soil was manured for all crops in the early spring, at the rate of about five tons of farm manure per acre. This was not sufficient to produce an average yield of maize on the heavy soil of these plats, but the growth of this crop was better than in 1910.

Soil samples for moisture and nitrates were taken to a depth of eight inches from the surface, and also to a depth of eight to sixteen inches. The plats were of the same size as those used in 1910 and each was divided into three sections: the north and the south sections were planted to a certain crop; the middle sections were unplanted and were given the same treatment as the planted sections. Each section of every plat was sampled separately, the sample consisting of three borings.

The results of the determinations of nitrates on the middle sections, representing the unplanted soil, and the averages for the north and south end sections, representing the planted soil, are presented in Table 17. The table gives the nitrates in parts per million for the surface eight inches and for the second eight inches, and the averages of these two depths:

TABLE 17. NITRATES IN SOIL OF PLANTED AND UNPLANTED SECTIONS OF PLATS, 1911 (PARTS PER MILLION)

First eight inches

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209 2401, 2409	Maize, mulched	26	61	59	39	17	5	14	17
2201, 2209 2401, 2409	None	27	54	79	64	46	14	32	18
2202, 2210 2402, 2410	Maize, scraped	32	50	41	121	76	58	71	32
2202, 2210 2402, 2410	None	23	49	53	112	141	135	176	199
2203, 2211 2403, 2411	Maize, cultivated	29	63	105	107	65	45	35	71
2203, 2211 2403, 2411	None	22	60	139	192	174	168	224	210
2204, 2212 2404, 2412	Maize, harvested August 1	30	38	130	116	105	158	139	119
2204, 2212 2404, 2412	None	34	42	140	168	139	215	163	196
2205, 2213 2405, 2413	Maize, planted June 26, harvested August 1	26	34	115	113	100	167	115	209
2205, 2213 2405, 2413	None	31	40	137	109	120	194	160	234
2206, 2214 2406, 2414	Potatoes	33	27	73	39	41	65	67	51
2206, 2214 2406, 2414	None	28	36	127	112	127	211	160	179
2207, 2215 2407, 2415	Oats	23	2	8	8	11	23	26	26
2207, 2215 2407, 2415	None	32	24	42	74	76	123	114	127
2208, 2216 2408, 2416	Oats, followed by maize	26	3	4	6	11	18	15	18
2208, 2216 2408, 2416	None	26	31	56	74	63	168	111	106

Second eight inches

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209 2401, 2409	Maize, mulched	22	29	25	22	15	13	16	13
2201, 2209 2401, 2409	None	19	26	33	29	34	27	50	23
2202, 2210 2402, 2410	Maize, scraped	15	21	28	20	15	12	23	18
2202, 2210 2402, 2410	None	14	21	41	21	27	24	44	42
2203, 2211 2403, 2411	Maize, cultivated	24	28	41	22	21	22	25	30

TABLE 17 (*continued*)

Second eight inches (*continued*)

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2203, 2211 2403, 2411	None	24	26	38	33	35	36	71	45
2204, 2212 2404, 2412	Maize, harvested August 1	29	19	29	27	28	36	42	51
2204, 2212 2404, 2412	None	22	19	30	30	30	42	61	65
2205, 2213 2405, 2413	Maize, planted June 26, harvested August 1	21	15	27	17	28	40	49	49
2205, 2213 2405, 2413	None	23	16	31	19	31	58	70	46
2206, 2214 2406, 2414	Potatoes	26	17	15	16	17	29	31	27
2206, 2214 2406, 2414	None	26	18	25	35	42	53	44	62
2207, 2215 2407, 2415	Oats	30	4	5	5	7	16	14	17
2207, 2215 2407, 2415	None	25	15	38	22	24	43	34	66
2208, 2216 2408, 2416	Oats, followed by maize	19	3	3	3	6	14	10	16
2208, 2216 2408, 2416	None	26	8	21	21	24	52	30	44

Average of first and second eight inches

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209 2401, 2409	Maize, mulched	24	45	42	30	16	9	15	15
2201, 2209 2401, 2409	None	23	40	56	46	40	20	41	30
2202, 2210 2402, 2410	Maize, scraped	23	35	34	70	45	35	47	25
2202, 2210 2402, 2410	None	18	35	47	66	84	79	110	120
2203, 2211 2403, 2411	Maize, cultivated	26	45	73	64	43	33	30	50
2203, 2211 2403, 2411	None	23	43	88	112	104	102	147	127
2204, 2212 2404, 2412	Maize, harvested August 1	29	28	79	71	66	97	90	85
2204, 2212 2404, 2412	None	28	30	89	99	89	128	112	130
2205, 2213 2405, 2413	Maize, planted June 26, harvested August 1	23	24	71	65	64	103	82	129
2205, 2213 2405, 2413	None	27	28	84	64	75	126	115	140

TABLE 17 (*concluded*)

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
Average of first and second eight inches (*continued*)									
2206, 2214 2406, 2414	Potatoes	29	22	44	27	29	47	49	39
2206, 2214 2406, 2414	None	27	27	76	73	84	132	102	120
2207, 2215 2407, 2415	Oats	21	3	6	6	9	19	20	21
2207, 2215 2407, 2415	None	28	19	40	48	50	83	74	96
2208, 2216 2408, 2416	Oats, followed by maize	22	3	3	4	8	16	12	17
2208, 2216 2408, 2416	None	26	19	38	47	43	110	70	75

A study of the nitrates as recorded in Table 17 shows that the maize, potatoes, and oats bear about the same comparative relation to the nitrate content of the soil that they did in previous years. This characteristic relationship between the crop and the nitrate content of the soil holds also, with some variation due to the season, for the different stages of growth of the plants.

In the first eight inches there is no tendency for the nitrates under the cultivated maize to run higher, at certain periods of growth, than the nitrates in the unplanted soil; but under the maize on the scraped and the late-planted plats the nitrates are higher during a part of the growing season than in the unplanted sections of these plats. In the second eight inches this is also the case.

The effect of all crops, and especially of oats, in depressing the nitrate content during the later stages of growth and afterwards is very marked, even when the nitrates in the unplanted soil continue to increase late into the autumn.

The maize that was harvested on August 1 did not reduce the nitrate content of the soil to the same extent after that date as did the maize not harvested at that time, but there was no tendency for the nitrates under the crop to increase relatively to the nitrates in the bare soil. This may mean that the maize plant uses a considerable quantity of nitrate

nitrogen during its later stages of growth, or it may mean that it merely has a depressing effect on nitrification.

Comparing the nitrates in the late-planted and early-harvested plats with those in the early-planted and early-harvested plats, it will be noticed that there is a greater increase in the nitrates in the former after the crop has been removed. Thus the very immature crop does not appear to have as depressing an effect as does the more mature one. A comparison, therefore, of the three sets of plats harvested and planted at different times indicates that it is the later stages of growth that interfere most with the process of nitrate formation.

The nitrates in the planted and the unplanted sections of the plats in cultivated maize, potatoes, and oats for the first and second eight inches of soil are shown in diagrams VI and VII. The moisture content of the soil on all the plats is given in Table 18:

TABLE 18. MOISTURE IN PLANTED AND UNPLANTED SECTIONS OF PLATS, 1911 (PERCENTAGE OF DRY SOIL)

		First eight inches							
Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209 2401, 2409	Maise, mulched	32.1	25.9	22.8	22.0	25.1	22.1	28.0	28.3
2201, 2209 2401, 2409	None	34.1	25.6	23.8	23.4	28.5	22.2	28.8	28.7
2202, 2210 2402, 2410	Maise, scraped	33.4	25.8	16.2	17.9	19.2	23.6	22.5	27.4
2202, 2210 2102, 2410	None	33.6	25.2	16.6	21.4	21.8	25.3	23.8	27.9
2203, 2211 2403, 2411	Maise, cultivated	31.4	23.2	24.9	16.5	17.7	20.0	23.4	26.2
2203, 2211 2403, 2411	None	31.4	24.2	26.6	20.3	20.8	23.6	25.3	26.6
2204, 2212 2404, 2412	Maise, harvested August 1	31.3	22.3	24.5	18.2	18.9	26.7	22.4	26.5
2204, 2212 2404, 2412	None	33.2	23.0	25.6	21.2	21.0	26.9	23.2	26.9
2205, 2213 2405, 2413	Maise, planted June 26, harvested August 1	32.4	21.6	24.0	18.7	19.0	26.4	22.0	27.2
2205, 2213 2405, 2413	None	32.2	22.0	24.7	19.3	19.2	26.3	22.2	28.0
2206, 2214 2406, 2414	Potatoes	32.8	21.6	22.2	15.6	15.9	25.4	21.3	26.1
2206, 2214 2406, 2414	None	34.0	22.7	24.7	19.4	18.7	26.6	22.4	26.8
2207, 2215 2407, 2415	Oats	33.1	18.1	7.2	11.3	12.7	22.3	25.9	24.6

TABLE 18 (*continued*)

First eight inches (*continued*)

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2207, 2215 2407, 2415	None	33.1	19.0	17.2	17.5	16.4	24.3	26.6	25.5
2208, 2216 2408, 2416	Oats, followed by maize	33.0	15.3	7.8	11.7	14.3	24.5	24.2	26.4
2208, 2216 2408, 2416	None	32.7	20.4	16.9	17.8	17.4	25.7	24.9	26.6

Second eight inches

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209 2401, 2409	Maize, mulched	26.6	21.7	19.0	18.3	21.1	19.1	22.6	22.7
2201, 2209 2401, 2409	None	26.6	21.4	19.9	20.9	23.3	18.9	22.9	23.6
2202, 2210 2402, 2410	Maize, scraped	25.4	20.9	16.6	15.9	15.6	19.2	19.0	21.7
2202, 2210 2402, 2410	None	25.6	22.0	17.0	17.9	18.7	21.2	20.2	23.7
2203, 2211 2403, 2411	Maize, cultivated	22.8	19.3	18.9	15.3	15.2	17.8	19.5	21.2
2203, 2211 2403, 2411	None	28.5	20.4	20.8	18.0	18.2	20.5	20.8	21.9
2204, 2212 2404, 2412	Maize, harvested August 1	27.4	18.9	19.2	16.8	17.6	21.6	19.7	21.9
2204, 2212 2404, 2412	None	25.0	18.2	20.2	18.0	18.3	20.8	19.8	21.4
2205, 2213 2405, 2413	Maize, planted June 26, harvested August 1	25.1	18.4	19.4	17.3	17.5	21.2	18.9	21.4
2205, 2213 2405, 2413	None	25.9	18.7	20.7	18.4	18.2	23.2	19.5	21.8
2206, 2214 2406, 2414	Potatoes	25.8	18.0	17.5	15.2	14.9	21.0	18.4	21.4
2206, 2214 2406, 2414	None	26.1	19.6	20.9	18.2	16.8	22.1	18.9	22.3
2207, 2215 2407, 2415	Oats	25.8	18.0	10.9	11.9	12.6	19.6	21.1	21.0
2207, 2215 2407, 2415	None	25.8	18.7	15.7	16.3	15.8	20.5	20.9	21.2
2208, 2216 2408, 2416	Oats, followed by maize	25.7	15.4	11.4	11.8	13.2	20.2	19.3	22.1
2208, 2216 2408, 2416	None	26.0	18.0	16.9	16.9	16.0	21.2	19.7	21.1

TABLE 18 (*concluded*)

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
	Average of first and second eight inches								
2201, 2209 2401, 2409	Maize, mulched	29.3	23.8	20.9	20.1	23.1	20.6	25.3	25.5
2201, 2209 2401, 2409	None	30.3	23.5	21.8	22.1	25.9	20.5	25.8	26.1
2202, 2210 2402, 2410	Maize, scraped	29.4	23.3	16.4	16.9	17.4	21.4	20.7	24.5
2202, 2210 2402, 2410	None	29.6	23.6	16.8	19.6	20.2	23.2	22.0	25.8
2203, 2211 2403, 2411	Maize, cultivated	27.1	21.2	21.9	15.9	16.4	18.9	21.4	23.7
2203, 2211 2403, 2411	None	29.9	22.3	23.7	19.1	19.5	22.0	23.0	24.2
2204, 2212 2404, 2412	Maize, harvested August 1	29.3	20.6	21.8	17.5	18.2	24.1	21.0	24.2
2204, 2212 2404, 2412	None	29.1	20.6	22.9	19.6	19.6	23.8	21.5	24.1
2205, 2213 2405, 2413	Maize, planted June 26, harvested August 1	28.7	20.0	21.7	18.0	18.2	23.8	20.4	24.3
2205, 2213 2405, 2413	None	29.0	20.3	22.7	18.8	18.7	24.7	20.8	24.9
2206, 2214 2406, 2414	Potatoes	29.3	19.8	19.8	15.4	15.4	23.2	19.8	23.7
2206, 2214 2406, 2414	None	30.0	21.1	22.8	18.8	17.7	24.3	20.6	24.5
2207, 2215 2407, 2415	Oats	29.4	18.0	9.0	11.6	12.6	20.9	23.5	22.8
2207, 2215 2407, 2415	None	29.4	18.8	16.4	16.9	16.1	22.4	23.7	23.3
2208, 2216 2408, 2416	Oats, followed by maize	29.3	15.3	9.6	11.7	13.7	22.3	21.7	24.2
2208, 2216 2408, 2416	None	29.3	19.2	16.9	17.3	16.7	23.4	22.3	23.8

There is no material lowering of the moisture content of the maize plats as compared with that of the unplanted soil. In the oat soil the moisture content is markedly lower, as compared with the unplanted soil, in July and August. The nitrate content does not appear to be greatly influenced thereby, as the nitrates during June are slightly lower than in July and August. As has been noted in previous years there appears to be no definite relation in this soil between the nitrate content of the soil under plants and the soil moisture, owing possibly to the fact that the soil was not at any time seriously depleted of moisture.

A comparison of the nitrates in the planted sections of the plats in terms of the nitrates in the unplanted sections, taking the latter in each case as 100, will serve to express more clearly the relation of the different

crops and treatments to the nitrate content of the soil. It will be remembered that the analyses of April 19 to 26 were made before the crops were planted. These data for the surface eight inches, for the second eight inches, and for the average of these two depths, are given in Table 19:

TABLE 19. RATIO OF NITRATES IN PLANTED SECTIONS OF PLATS TO NITRATES IN UNPLANTED SECTIONS

First eight inches

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209, 2401, 2409	Maize, mulched	96	113	75	61	37	36	44	94
2202, 2210, 2402, 2410	Maize, scraped	139	102	77	108	54	43	40	16
2203, 2211, 2403, 2411	Maize, cultivated	132	105	75	56	37	27	16	34
2204, 2212, 2404, 2412	Maize, harvested August 1	88	90	93	69	76	73	85	61
2205, 2213, 2405, 2413	Maize, planted June 26, harvested August 1	84	85	84	104	83	86	72	89
2206, 2214, 2406, 2414	Potatoes	118	75	57	35	32	31	42	28
2207, 2215, 2407, 2415	Oats	72	8	19	11	14	19	23	20
2208, 2216, 2408, 2416	Oats, followed by maize	100	10	7	8	17	11	13	17

Second eight inches

Plat	Crop	April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209, 2401, 2409	Maize, mulched	116	112	76	76	44	48	32	57
2202, 2210, 2402, 2410	Maize, scraped	107	100	68	95	56	50	52	43
2203, 2211, 2403, 2411	Maize, cultivated	100	108	108	67	60	61	35	67
2204, 2212, 2404, 2412	Maize, harvested August 1	132	100	74	90	72	86	69	78
2205, 2213, 2405, 2413	Maize, planted June 26, harvested August 1	91	94	87	89	90	69	70	107
2206, 2214, 2406, 2414	Potatoes	100	94	60	46	40	55	70	44
2207, 2215, 2407, 2415	Oats	80	27	13	23	29	37	41	26
2208, 2216, 2408, 2416	Oats, followed by maize	73	37	14	14	25	27	33	36

TABLE 19 (*continued*)
(See tables 1, 5, 6, 7, 8)

Plat	Crop	Average of first and second eight inches							
		April 19 to 26	June 16 to 27	July 10 to 21	August 4 to 14	August 16 to 24	August 31 to September 18	September 20 to October 5	October 9 to November 4
2201, 2209, 2401, 2409	Maise, mulched	104	112	75	65	40	45	37	75
2202, 2210, 2402, 2410	Maise, scraped	128	100	72	106	54	44	43	21
2203, 2211, 2403, 2411	Maise, cultivated	113	105	83	57	41	32	20	39
2204, 2212, 2404, 2412	Maise, harvested August 1	104	93	88	72	74	76	80	65
2205, 2213, 2405, 2413	Maise, planted June 26, harvested August 1	85	86	85	102	85	82	71	92
2206, 2214, 2406, 2414	Potatoes	107	81	58	37	35	36	48	32
2207, 2215, 2407, 2415	Oats	75	16	15	12	18	23	27	22
2208, 2216, 2408, 2416	Oats, followed by maize	85	16	8	8	19	15	17	23

The analyses of April 19 to 26 were all made before any of the crops were planted, and therefore they represent the natural relation of the respective sections of the plats when uninfluenced by plants. In the maize plats there is a tendency for the nitrates under the crop to increase sometime during the growing season in the scraped plat and in the two plats harvested August 1. The other two maize plats do not show this tendency.

As has been remarked before, there appears to be a relation between the size of the crop and the tendency of the nitrates to increase during the active growing season. It is impossible to compare the yields on the early-harvested plats with those on the other plats, but of the late-harvested plats those that increased in nitrates during the early part of the growing season were the ones that yielded least — namely, the scraped plats 2202, 2210, 2402, 2410. The yields of these plats are stated in Table 20:

TABLE 20. YIELDS OF MAIZE (GRAIN AND FODDER) ON PLATS HARVESTED AT MATURITY

Plat	Treatment	Weight of crop (grams per plat)	Nitrogen in crop (grams per plat)
2201, 2209, 2401, 2409	Mulched	16,457	123
2202, 2210, 2402, 2410	Scraped	13,369	98
2203, 2211, 2403, 2411	Cultivated	17,425	135

Both the yield of plant substance and the nitrogen in the crop are least on the scraped plats, which are the ones that exhibit a tendency for the nitrates to increase during the growing period. This would indicate that the utilization of nitrates is greater on the plats producing larger yields; but that the high nitrate content of the maize plats cannot be due entirely to this is evidenced by the fact that the nitrates under the plants are higher in August than are the nitrates in the unplanted soil.

During the later stages of growth the maize plats harvested at maturity all decrease in nitrates at about the same rate. In this respect they differ from the plats that were harvested August 1, which maintain a higher nitrate content during the latter part of the season as has already been mentioned.

The marked falling-off in the nitrates after the middle of August on the plats of maize harvested at maturity as compared with the high nitrate content earlier in the season is not in keeping with the nitrogen absorption by the crop during the early and the later part of the season. Yields and analyses of the maize on these plats showed that by August 1 the maize plants had absorbed 44 per cent of all their nitrogen. During the early period the nitrate content of the planted soil was increasing nearly as rapidly as, and in some cases more rapidly than, that of the unplanted soil. After the middle of August, by which time fully 50 per cent of the nitrogen must have been absorbed, the nitrate content of the planted soil decreased very markedly while the nitrate content of the unplanted soil increased. If the decreased nitrate content in the planted soil were caused by nitrogen absorption exclusively, there would be a tendency for the nitrates in the planted soil to increase as do the nitrates in the unplanted soil; but in general there is no such tendency even late in the season, when nitrogen absorption must have ceased. This again indicates a depressing influence of the plant on nitrification during the later stages of growth.

Comparing the oat plats planted to maize after the oats were harvested with those kept unplanted, it will be seen that there is a tendency for the nitrates to run higher in the latter. This indicates that the growth of the young maize plants has stimulated the formation of nitrates and has overcome the depressing influence of the mature oat plants.

In diagrams VIII to XV these relations of nitrates under the plants to those in the unplanted soil of the corresponding plats are shown graphically.

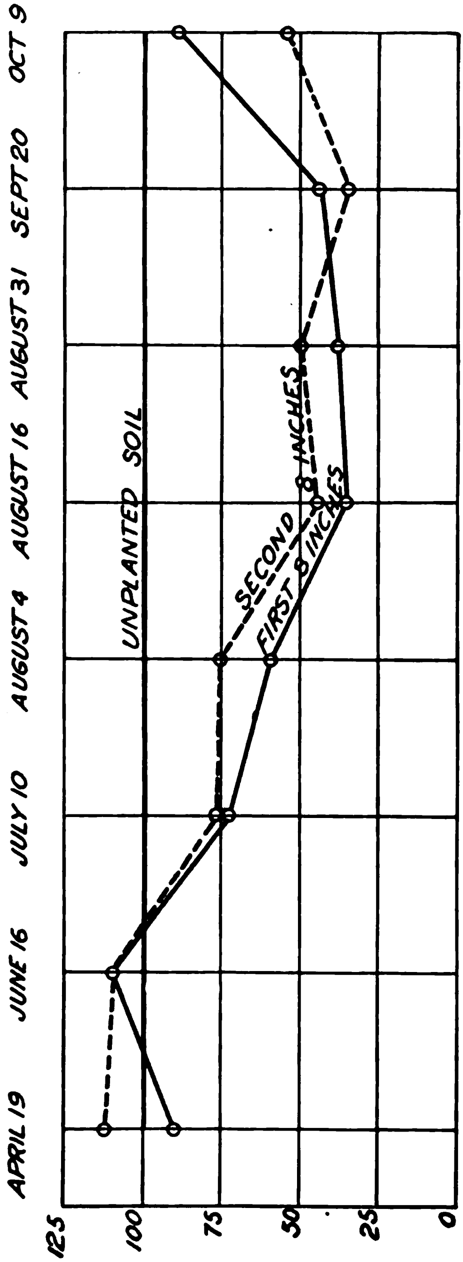

DIAGRAM VIII.—*Relative nitrate content of soil under maize mulched, 1911*

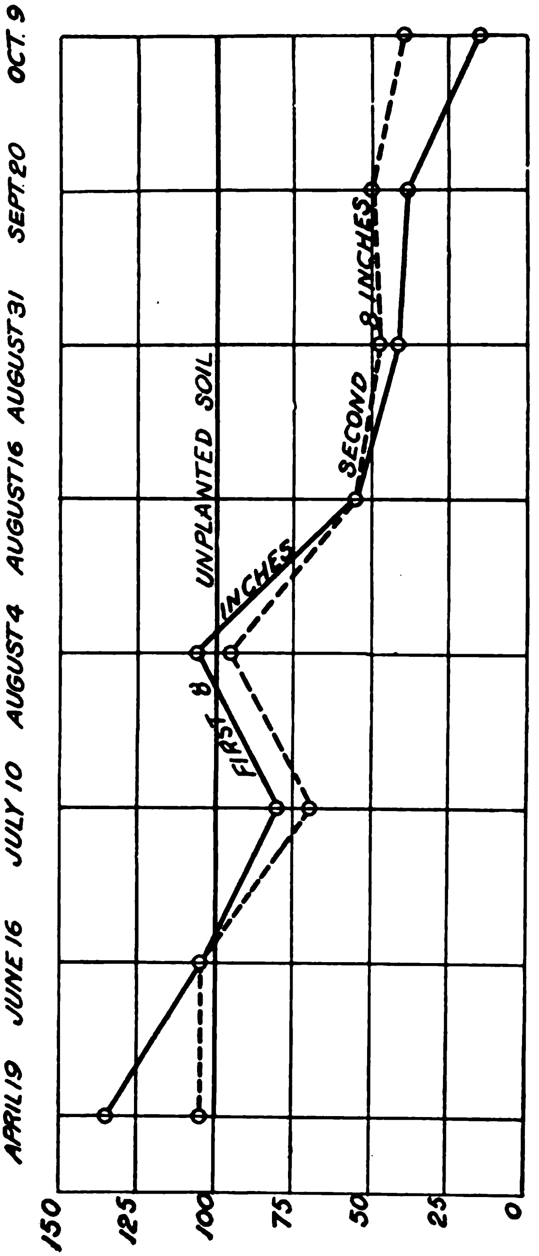

DIAGRAM IX.—*Relative nitrate content of soil under maize scraped, 1911*

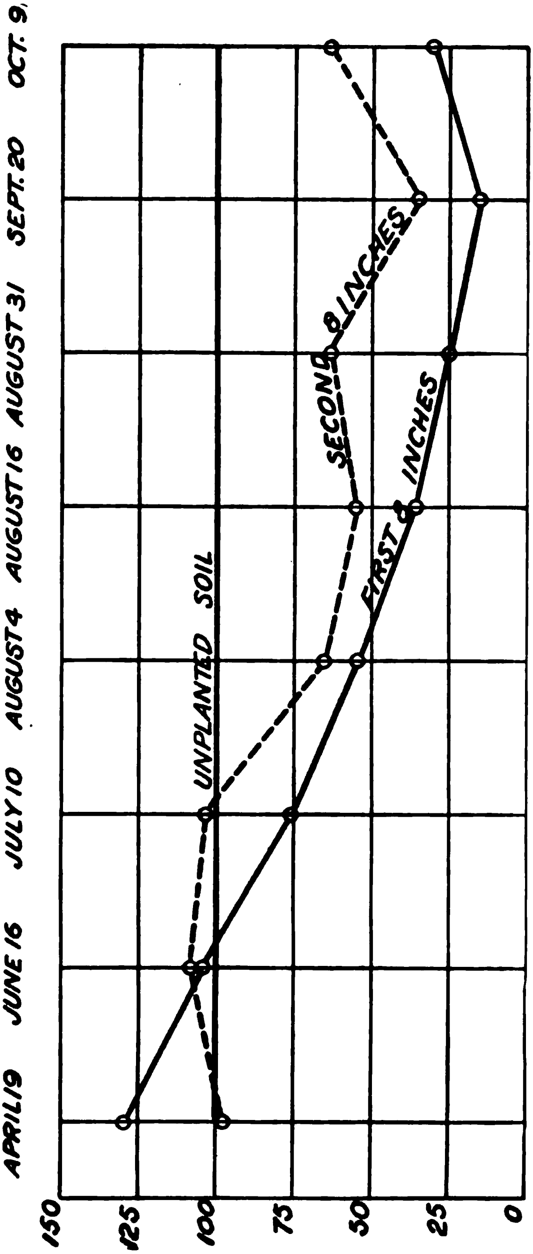

DIAGRAM X.— *Relative nitrate content of soil under maize cultivated, 1911*

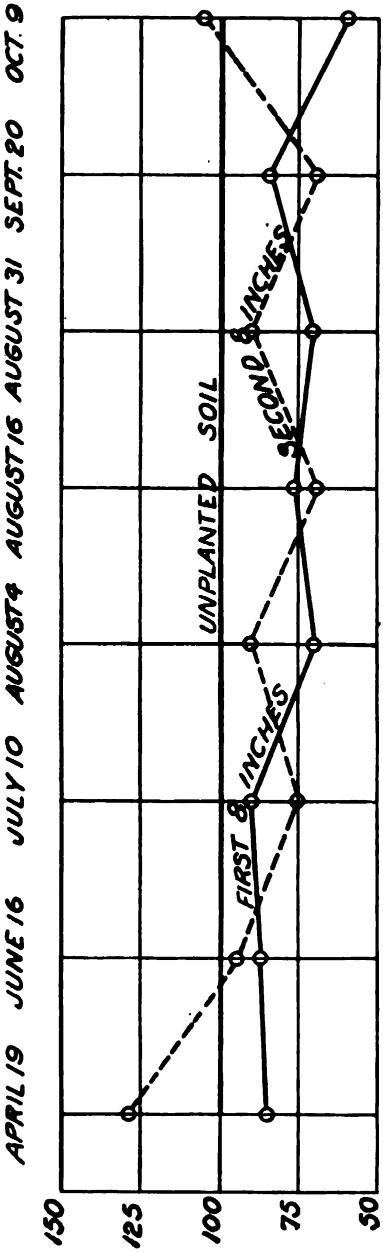

DIAGRAM XI.—*Relative nitrate content of soil under maize harvested August 1 and cultivated after harvest, 1911*

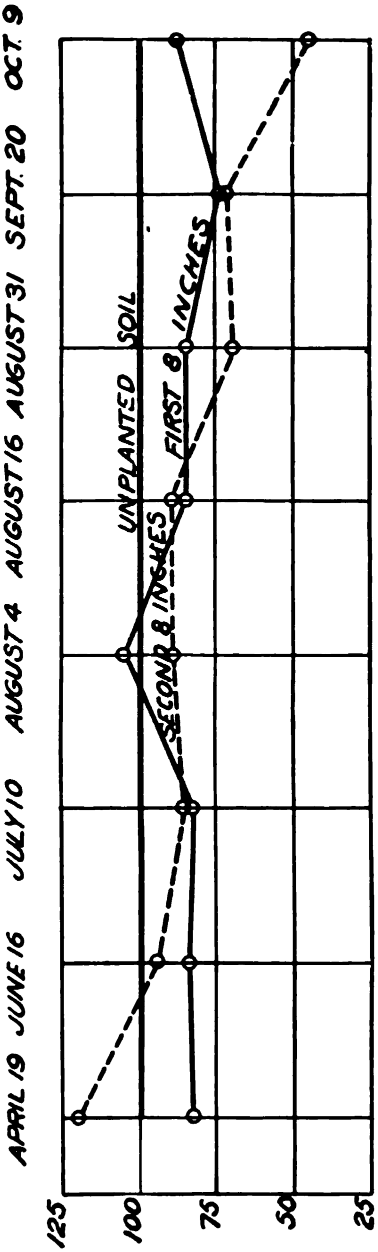

DIAGRAM XII.—*Relative nitrate content of soil under maize planted June 26, harvested August 1, and cultivated after harvest, 1911*

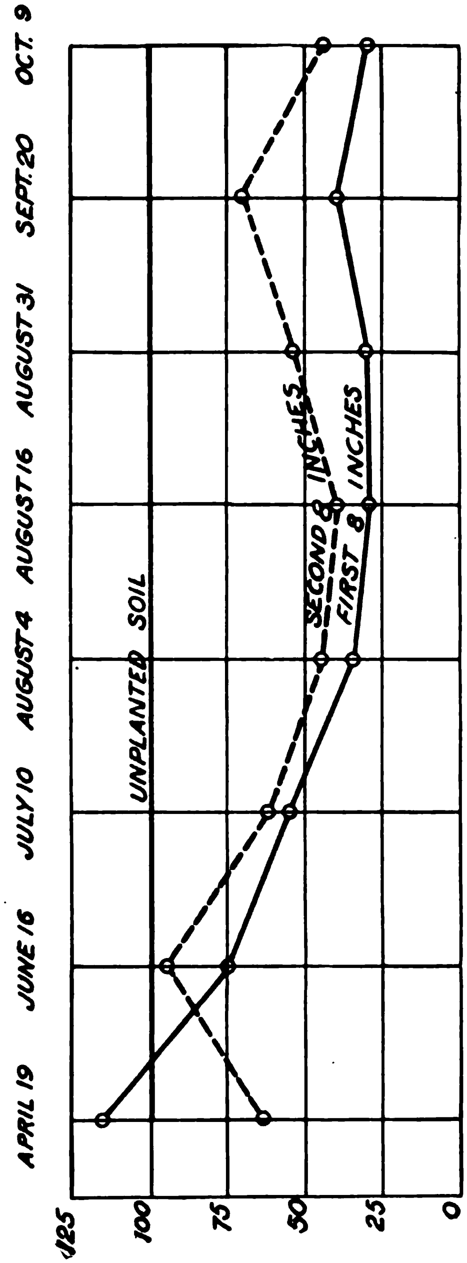

DIAGRAM XIII.—*Relative nitrate content of soil under potatoes, 1911*

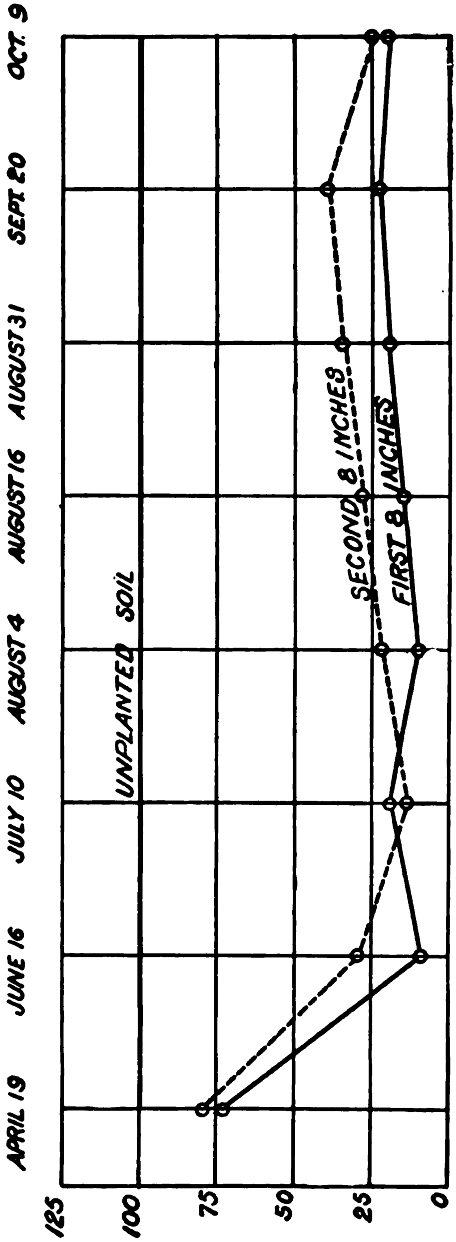

DIAGRAM XIV.— *Relative nitrate content of soil under oats cultivated after harvest, 1911*

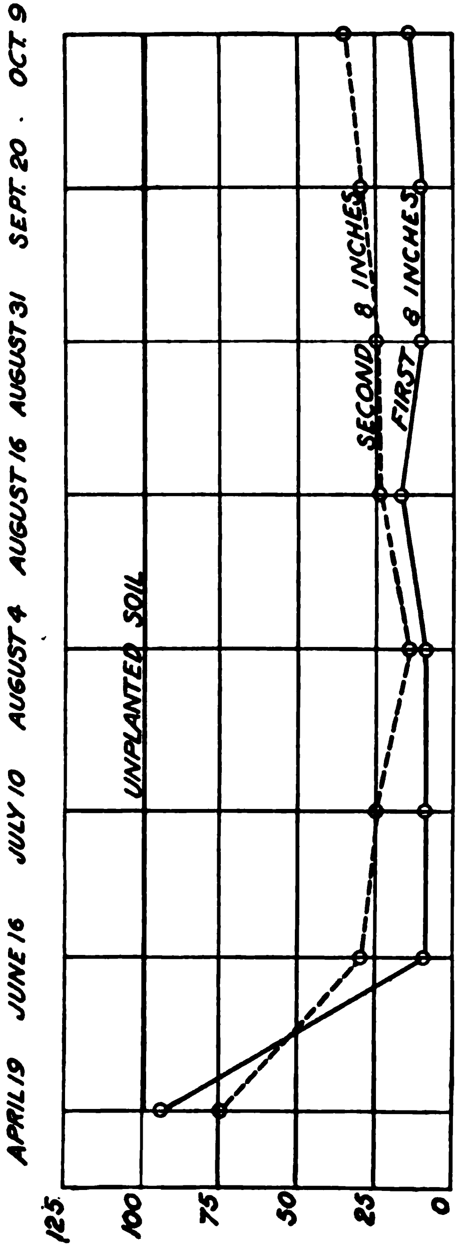

DIAGRAM XV.—*Relative nitrate content of soil under oats followed by maize, 1911*

Experiments in 1912

The plats used in 1911 were planted in 1912 to the same kinds of crops that were grown on them in the previous year. It was thought that this might give a cumulative effect of the crop on the soil. As before, the middle sections of the plats were not planted. In one respect the plats were different from those used in 1910 and 1911, in which cases the entire plats had been planted to some crop in the preceding years. The middle sections had therefore been fallowed for two years. As a result of the fallow of the previous year the nitrates in the middle sections were much higher in spring than those in the planted sections, except in the mulched maize plats where the difference was not great.

The arrangement of the plats and their treatment, as given below, differed only in time of planting and harvesting from that of 1911:

Plat	Crop and soil treatment
2201, 2209, 2401, 2409	Maize planted May 22. Mulched
2202, 2210, 2402, 2410	Maize planted May 22. Scraped
2203, 2211, 2403, 2411	Maize planted May 22. Cultivated all summer
2204, 2212, 2404, 2412	Maize planted May 22, harvested August 20, and allowed to regrow. Cultivated all summer
2205, 2213, 2405, 2413	Maize planted July 5, harvested August 20. Cultivated all summer
2206, 2214, 2406, 2414	Potatoes planted May 23. Cultivated
2207, 2215, 2407, 2415	Oats planted May 21. Cultivated after harvest
2208, 2216, 2408, 2416	Oats planted May 21, followed by maize. Cultivated the maize

The temperature during the growing season was somewhat below normal. The first half of July was the warmest part of the summer. Rainfall was deficient in June and July and the yield of oats was lessened by the drought. Growth continued later than usual in the autumn because of the warm, moist weather in September. Potatoes were fully mature about the middle of September and maize was harvested on October 20, except on the early-harvested plats.

No manure nor fertilizer was applied to the soil. The growth of all crops was normal but the yields were not large.

TABLE 21. NITRATES IN SOIL OF PLANTED AND UNPLANTED SECTIONS OF PLATS, 1912. SURFACE TEN INCHES (PARTS PER MILLION)

Plat	Crop	April 19	April 27	June 10	June 17	June 24	July 1	July 8	July 15	July 22	July 29	August 5	August 12	August 19	August 26	September 3	September 9	September 16	September 26	October 1	October 7	October 18
2201, 2209, 2401, 2409	Maize, mulched	19	17	40	26	30	37	37	50	60	58	60	51	47	47	24	17	...	22	13	25	26
2201, 2209, 2401, 2409	None	22	23	43	28	38	32	39	42	56	64	53	52	55	76	52	29	...	34	32	30	36
2202, 2210, 2402, 2410	Maize, scraped	27	34	42	30	29	33	45	48	63	60	46	70	54	63	39	47	38	27	26	36	34
2202, 2210, 2402, 2410	None	66	68	67	65	54	53	53	74	85	103	79	100	89	93	47	55	57	69	104	70	79
2203, 2211, 2403, 2411	Maize, cultivated	28	30	39	36	34	41	41	57	52	62	54	71	50	84	50	29	29	29	19	30	26
2203, 2211, 2403, 2411	None	54	65	69	52	60	64	80	76	90	113	101	125	107	123	119	74	69	68	72	64	73
2204, 2212, 2404, 2412	Maize, harvested August 20	47	39	50	42	47	45	53	54	78	65	71	81	75	93	70	53	48	60	103	58	76
2204, 2212, 2404, 2412	None	60	62	64	48	56	56	68	87	87	120	122	110	101	116	100	89	75	49	85	98	111
2205, 2213, 2405, 2413	Maize, planted July 5, harvested August 20	59	60	52	50	68	65	73	67	83	86	103	118	104	111	86	90	84	102	73	84	83
2205, 2213, 2405, 2413	None	78	69	52	57	61	90	69	70	109	104	103	153	103	135	114	104	91	103	90	106	106
2206, 2214, 2406, 2414	Potatoes	22	29	33	35	39	35	62	46	45	82	58	66	61	55	29	31	31	14	24	28	53
2206, 2214, 2406, 2414	None	45	49	60	57	88	69	62	78	79	83	95	118	116	105	94	71	104	83	43	111	124
2207, 2215, 2407, 2415	Oats	31	26	28	27	31	13	15	17	12	19	31	10	8	9	14	22	15	13	20	...	...
2207, 2215, 2407, 2415	None	70	44	69	64	64	70	90	58	70	99	103	112	92	105	104	134	102	102	105	...	...
2208, 2216, 2408, 2416	Oats, followed by maize	25	22	30	30	26	20	11	13	10	18	9	10	7	11	13	17	14	16	34	...	...
2208, 2216, 2408, 2416	None	77	54	52	47	60	43	46	63	61	58	86	84	81	80	71	76	96	95	72	...	...

TABLE 22. MOISTURE IN PLANTED AND UNPLANTED SECTIONS OF PLATS, 1912. SURFACE TEN INCHES (PERCENTAGE OF DRY SOIL)

Plat	Crop	April 19	April 27	June 10	June 17	June 24	July 1	July 8	July 15	July 22	July 29	August 5	August 12	August 19	August 26	September 3	September 9	September 16	September 26	October 1	October 7	October 18
2201, 2209, 2401, 2409	Maize, mulched	28.1	25.5	22.6	20.7	20.6	21.0	20.6	20.1	22.7	21.8	25.6	25.8	25.9	25.7	26.5	25.8	26.2	27.8	27.0	26.6	25.2
2201, 2209, 2401, 2409	None	27.9	23.9	22.4	20.4	20.3	21.5	20.8	20.0	21.2	22.3	26.4	25.5	26.3	26.3	23.3	26.4	27.6	26.8	26.9	27.0	24.8
2202, 2210, 2402, 2410	Maize, scraped	26.1	25.8	21.7	19.5	19.4	18.2	17.3	16.7	18.4	17.2	21.1	22.5	20.5	21.8	24.2	23.2	24.3	25.6	25.4	24.0	22.4
2202, 2210, 2402, 2410	None	26.7	26.9	20.1	19.2	18.8	18.3	17.2	17.1	19.2	18.6	21.9	23.4	21.3	25.9	24.0	23.9	25.1	25.2	25.6	24.4	22.9
2203, 2211, 2403, 2411	Maize, cultivated	26.7	25.9	20.3	18.9	19.0	18.6	18.9	18.6	19.1	21.1	22.7	24.4	24.3	22.9	24.0	22.5	23.8	24.9	25.6	23.6	22.2
2203, 2211, 2403, 2411	None	28.1	26.6	20.7	19.6	19.2	19.5	18.9	19.9	19.4	21.5	23.6	24.1	24.7	18.9	24.5	23.4	24.4	25.0	26.7	23.9	22.8
2204, 2212, 2404, 2412	Maize, harvested August 20	25.2	24.4	19.4	18.8	19.2	18.7	18.1	18.7	18.9	20.5	22.5	23.1	23.1	23.1	23.3	22.2	22.8	24.7	25.0	23.8	21.3
2204, 2212, 2404, 2412	None	26.4	24.5	19.3	18.4	19.1	18.7	18.0	18.5	18.9	20.9	22.8	23.8	24.1	23.2	24.0	22.4	23.4	24.9	25.6	23.6	21.8
2205, 2213, 2405, 2413	Maize, planted July 5, harvested August 20	24.7	24.2	19.8	18.0	18.6	18.2	17.9	18.2	18.6	21.3	21.7	23.2	22.2	22.7	22.9	23.3	22.8	24.4	24.8	24.4	21.7
2205, 2213, 2405, 2413	None	25.0	24.5	20.9	18.9	18.9	18.9	18.1	18.7	18.8	21.9	22.1	23.6	22.8	17.6	23.9	23.3	22.5	24.8	24.6	24.5	23.4
2206, 2214, 2406, 2414	Potatoes	26.7	25.9	19.4	18.4	18.8	18.2	17.4	17.9	17.9	20.6	21.4	22.8	21.7	21.4	23.0	23.4	22.5	24.3	24.8	24.0	22.3
2206, 2214, 2406, 2414	None	28.6	25.2	20.0	19.5	19.5	18.8	18.7	18.8	19.5	21.4	22.1	23.7	20.3	17.2	23.0	24.4	22.9	24.7	25.0	25.0	22.7
2207, 2215, 2407, 2415	Oats	27.0	24.9	20.2	18.0	18.6	15.9	13.9	12.8	12.9	17.4	17.4	19.8	20.0	21.1	23.6	23.8	23.1	26.0	24.4	....	....
2207, 2215, 2407, 2415	None	27.4	24.5	22.0	20.7	21.8	20.4	18.1	17.8	17.6	21.5	20.5	20.8	21.0	21.8	23.7	23.3	20.3	26.2	24.7	....	....
2203, 2216, 2408, 2416	Oats, followed by maize	27.4	24.8	20.6	18.4	18.9	15.8	13.6	12.2	12.2	17.7	17.3	19.7	20.1	21.4	23.6	22.8	22.8	25.9	24.1	....	....
2203, 2216, 2408, 2416	None	27.7	25.4	21.6	20.8	21.3	20.0	18.8	18.1	17.7	20.9	21.1	21.7	21.7	21.6	23.0	22.6	23.1	26.0	23.0	....	....

TABLE 23. RATIO OF NITRATES IN PLANTED SECTIONS OF PLATS TO NITRATES IN UNPLANTED SECTIONS

Plat	Crop	April 19	April 27	June 10	June 17	June 24	July 1	July 8	July 15	July 22	July 29	August 5	August 12	August 19	August 26	September 3	September 9	September 16	September 26	October 1	October 7	October 18
2201, 2209, 2401, 2409	Maize, mulched	86	74	93	93	79	116	95	119	107	91	113	98	85	62	46	59	...	65	41	83	72
2202, 2210, 2402, 2410	Maize, scraped	41	50	63	46	54	62	85	65	74	58	58	70	61	68	83	85	67	39	25	51	43
2203, 2211, 2403, 2411	Maize, cultivated	52	46	57	69	57	64	51	75	58	55	53	57	47	68	42	39	42	43	26	47	36
2204, 2212, 2404, 2412	Maize, harvested August 20	78	63	78	87	84	80	78	62	90	54	58	74	74	80	70	60	64	122	121	59	68
2205, 2213, 2405, 2413	Maize, planted July 5, harvested August 20	76	87	100	88	111	72	106	96	76	83	106	77	101	82	75	87	92	99	81	79	78
2206, 2214, 2406, 2414	Potatoes	49	59	55	61	44	51	100	59	57	99	61	56	53	52	30	44	30	17	56	25	43
2207, 2215, 2407, 2415	Oats	44	59	41	42	48	19	17	29	17	19	30	9	9	9	13	16	15	13	19	...	...
2208, 2216, 2408, 2416	Oats, followed by maize	32	41	58	64	43	46	24	21	16	31	10	12	9	14	18	22	15	17	47	...	...

Soil samples for moisture and nitrates were taken to a depth of ten inches except on the cultivated plats, on which the surface two inches was removed before boring and the samples were taken to a depth of ten inches under the layer removed. The reason for removing the surface two inches on these plats was to eliminate from the samples the loose, dry layer, in which nitrate formation would not be expected to proceed under the same influences that operate in the moist soil below. In Diagram XVI is shown the course of the nitrates under the cultivated maize and under potatoes and oats.

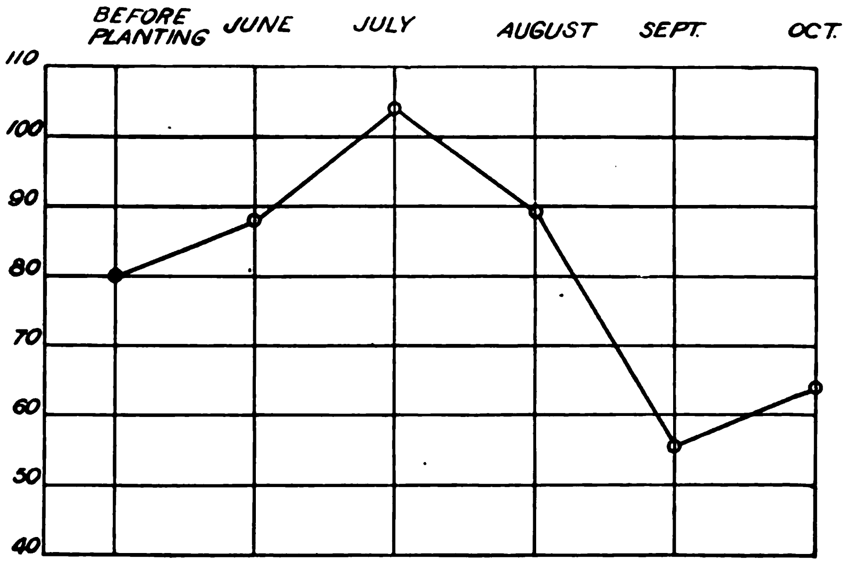

DIAGRAM XVII.—*Relative nitrate content of soil under maize mulched, 1912*

The nitrate content and the moisture content of the soil on the planted and unplanted sections of all plats are shown in tables 21 and 22. The characteristic relationship between the crop and the nitrate content of the soil is again apparent in the former table, nitrates being higher under maize than under potatoes during the active growing period and being lowest under oats.

Nitrates are sometimes higher in the soil under maize than in the unplanted soil on the mulched plats; but the nitrates are so high in the

unplanted soil of the other maize plats, owing to the fallow of the previous year, that only on the late-planted plats are the nitrates at any time actually higher under the crop than on the bare soil.

The relations of the crops to nitrates are well brought out in Table 23 and in diagrams XVII to XXIV. The figures on which these diagrams are based have been obtained by considering the nitrates in the bare spaces as 100 and calculating, on that basis, the nitrates in the planted sections of the plats. These percentages are then grouped into periods embracing all the analyses before planting, and the analyses after planting by months or such parts of months as elapsed before harvest.

The mulched maize plats, represented in Diagram XVII, show a maximum nitrate content in July, at which time the nitrates were higher under the maize than in the bare soil. After that there is a decrease to September and a slight increase in October.

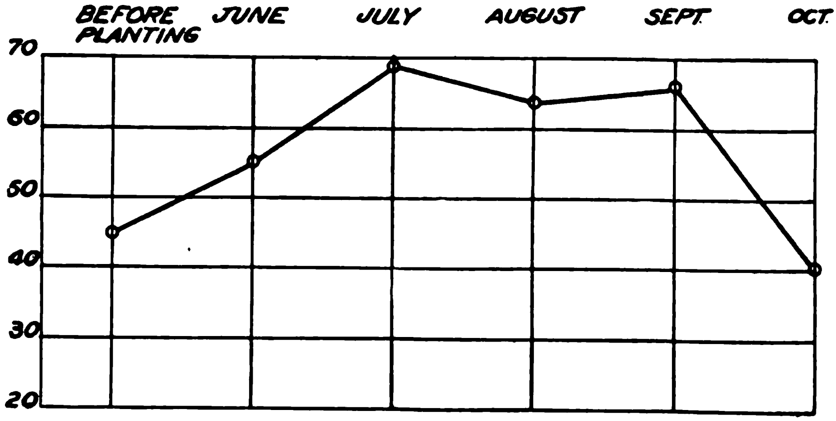

DIAGRAM XVIII.— *Relative nitrate content of soil under maize scraped, 1912*

The scraped maize plats, represented in Diagram XVIII, show a maximum nitrate content in July, but it is not so high under maize as in the unplanted soil. There is a decrease after July.

The cultivated maize plats, represented in Diagram XIX, correspond in the main with the previous plats. All these maize plats exhibit the characteristic stimulation of nitrate formation in midsummer and partial inhibition in late summer and in the fall.

The maize plats planted on May 22 and harvested on August 20 are represented in Diagram XX. The maize on these plats was allowed to regrow after harvest; in this respect the treatment differed from that of the

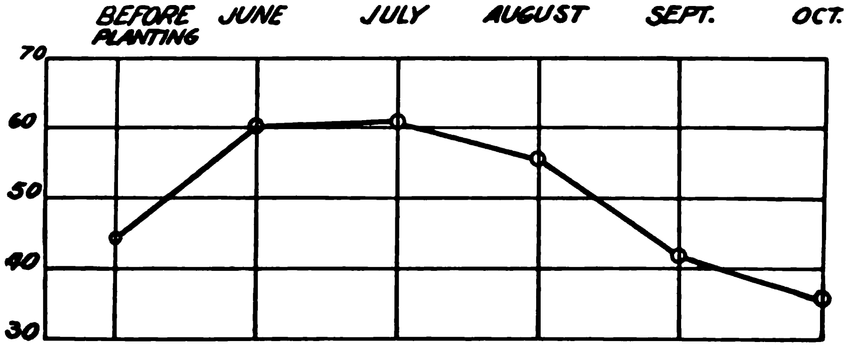

DIAGRAM XIX.—*Relative nitrate content of soil under maize cultivated, 1912*

previous year. The August figures are based on the analyses made previous to August 20. In September and October there is an increase in the nitrate content of the soil. If the regrowth of maize has a stimulating effect on nitrate formation this increase is to be expected, as the maize made a regrowth of about eighteen inches.

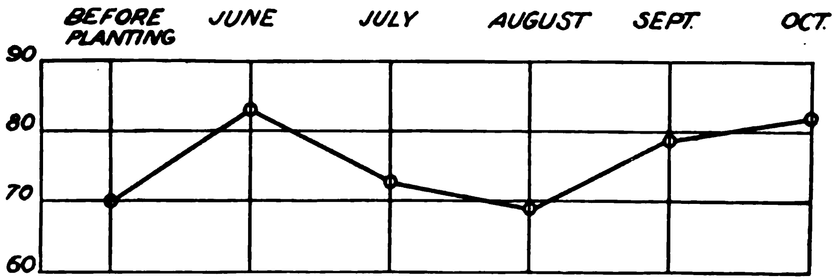

DIAGRAM XX.—*Relative nitrate content of soil under maize harvested August 20 and allowed to regrow, 1912*

It will be noted that this was the only set of maize plats in which any marked increase of nitrates occurred. The increase of nitrates under maize at this time of year and coincident with the regrowth, is evidence that

the time of year is not the only determining factor in the formation of nitrates; nor is the decrease of nitrates during the later stages of growth due

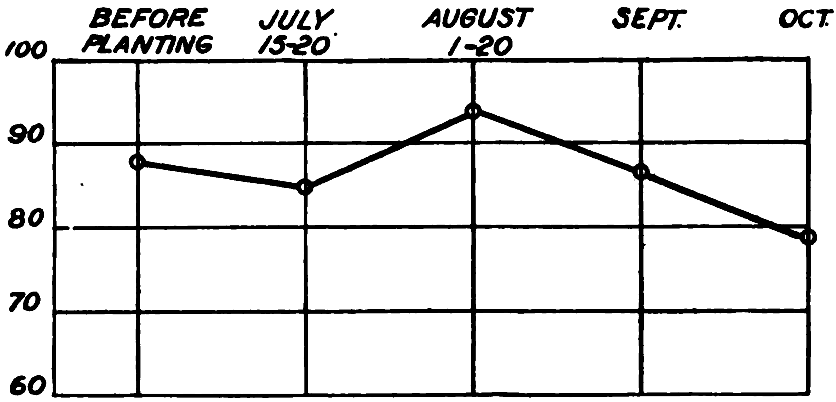

DIAGRAM XXI.—*Relative nitrate content of soil under maize planted July 5, harvested August 20, 1912*

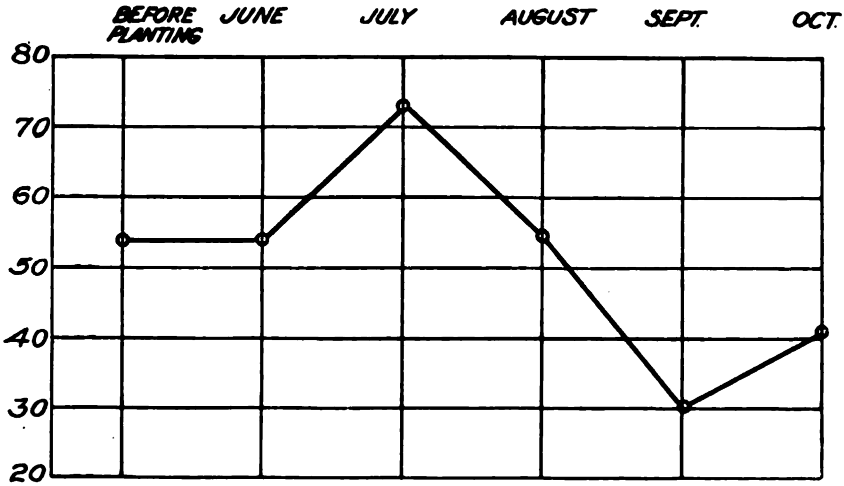

DIAGRAM XXII.—*Relative nitrate content of soil under potatoes, 1912*

entirely to the removal of easily nitrifiable organic matter, otherwise the nitrate content would not have risen in the soil on which a regrowth of maize occurred.

Nitrates in the late-planted maize plats are shown in Diagram XXI. Owing to the late planting — July 5 — the nitrates never fall very low and are highest in August; this is another indication that the time of year is not the controlling factor in the maximum nitrate content. Following the harvest of this maize on August 20 there is a decrease in nitrates.

The nitrates under potatoes are shown in Diagram XXII. As in pre-

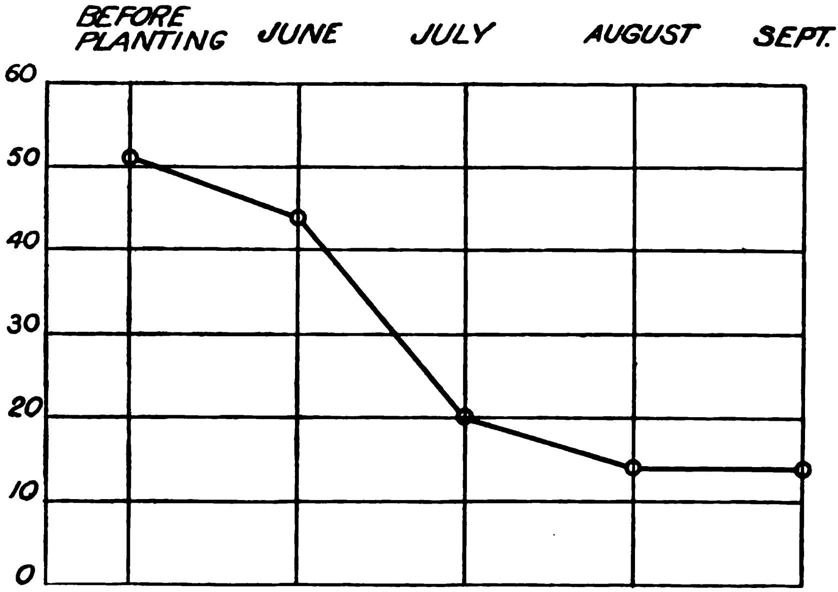

DIAGRAM XXIII.— *Relative nitrate content of soil under oats, cultivated after harvest, 1912*

vious years the maximum nitrate content occurs in July, and the nitrates decrease from that time until the close of the season.

The oat plats, represented in diagrams XXIII and XXIV, show the characteristic decline in nitrates, except in the plats on which maize was planted after the oats were harvested. In these plats there was a slight rise of nitrates in September; but, since the maize grew only five or six inches high, the effect on the nitrates was unimportant.

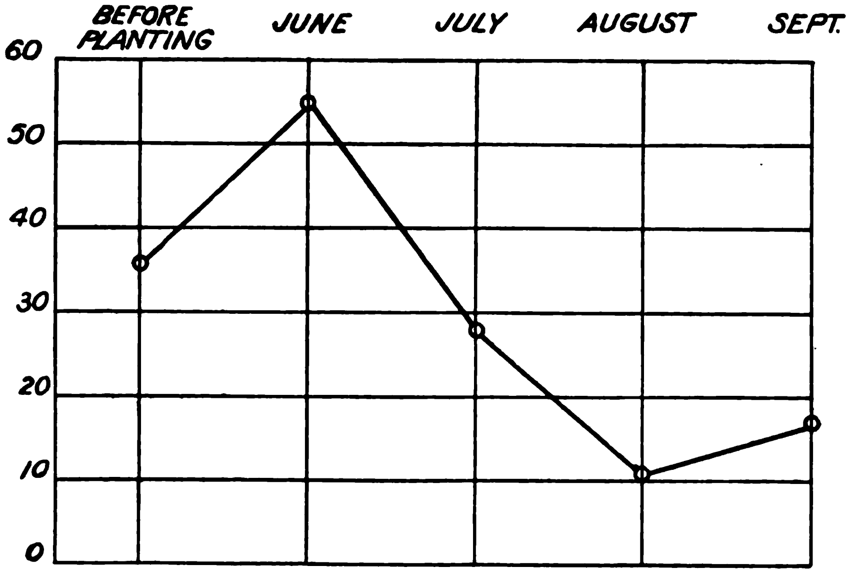

DIAGRAM XXIV.— *Relative nitrate content of soil under oats followed by maize, 1912*

The relation of the nitrate content of the soil to the quantities of nutrients removed by crops

It has been suggested by a number of investigators that the bacterial activity of the soil is dependent on the supply of readily soluble mineral nutrients that it contains. Assuming this to be true, the question arises whether a certain crop might influence the production of nitrates in the soil by removing a greater or less quantity of the soluble mineral nutrients.

As maize and oats have been grown in this experiment for a number of years, it is possible to make some comparisons between these two plants in regard to the quantities of nutrients removed and to the nitrate content of the soil during the latter part of the season, when the removal of the nutrient substances may be expected to affect the nitrate content.

The crops removed from the plats used in these experiments were all sampled and the total nitrogen was determined. Unfortunately, the ash was not analyzed, therefore no exact figures are obtainable for the mineral constituents; but, since the variation in yields between the two crops, maize and oats, was very large, probably the error introduced by employ-

ing an average figure for the percentage of mineral constituents would be insignificant as compared with the differences in the quantities removed in the crops. The percentages of phosphoric acid (P_2O_5) and potash (K_2O) given in the Yearbook of the Department of Agriculture for 1894 (pages 565 to 568) have been used.

In Table 24 are given the relative quantities of nitrogen, phosphoric acid, and potash removed in the maize and oat crops, and the relative nitrate contents of the plats at the time of harvest or as near that date as is practicable:

TABLE 24. RELATIVE QUANTITIES OF NUTRIENTS REMOVED BY MAIZE AND OATS AND RELATIVE NITRATE CONTENTS OF THE SOIL AT HARVEST

	1908 Maize	1909 Oats	1910	
			Maize	Oats
Relative yields of				
Dry matter	100	72	100	755
Nitrogen	100	71	100	828
Phosphoric acid	100	91	100	1,523
Potash	100	176	100	1,265
Dates of nitrate determinations	Sept. 17	Aug. 7	Oct. 17	Aug. 17
Relative nitrate contents of soil	100	7	100	34

It will be noticed that in 1908 and 1909 the oat crop was small as compared with the maize crop, while in 1910 it was relatively very large. In both instances the nitrate content of the oat soil was characteristically much lower than that of the maize soil. The characteristic relation of nitrate content under oats and under maize appears to be independent of the quantities of nutrients removed by the crops.

The influence of alfalfa and of timothy on the production of nitrates in soil

On the experiment field in which most of the experiments just described were conducted, and consequently on similar soil, certain plats had been seeded to alfalfa and contiguous plats to timothy in the spring of 1906. These plats remained continuously in the same crops until the fall of 1911. At the time when the seeding was done, part of the land planted to each of

the crops received an application of quicklime at the rate of 2000 pounds per acre. Alfalia roots on both limed and unlimed soil possessed tubercles. In the spring of 1910 strips of land through both the limed and the unlimed parts of the alfalfa and the timothy plats were hoed bare of vegetation, and these strips were kept free from plants of all kinds during 1910 and 1911.

The nitrate-producing power of alfalfa soil and of timothy soil

The rate at which nitrate formation takes place in soil is well known to be influenced by a number of conditions, such as the basicity of the soil, the degree of aeration, and the like. That it may be influenced by the nature of the vegetation growing on the soil appears to be true of the soil used in these experiments. The method adopted for measuring nitrate production was as follows: The soil was sampled by means of a soil auger to a depth of eight inches. The borings from the plat or section of plat to be tested were mixed, quartered, and placed in an air-tight jar while still moist. When the jar was brought to the laboratory, moisture and nitrates were determined within twelve hours after sampling. Nitrates were determined in 100 grams of moist soil by means of the disulfonic-acid method. Another 100 grams of moist soil was placed in a bottle having a capacity of 250 cubic centimeters, and sufficient water was added to bring the moisture content to 25 per cent of the dry weight of the soil. A loose cotton plug was inserted into the mouth of the bottle, which was then placed in an incubator and kept at a temperature of 30° C. for the number of days stated in the following tables. In some of the earlier tests, 500 milligrams of ammonium sulfate was added to each 100 grams of soil; this practice was afterwards abandoned, however, and does not apply to results obtained after 1910. Tests were made also by adding 100 milligrams of dried blood to 100 grams of soil and incubating as above. The soil for the test without dried blood and the soil for the test with dried blood were weighed out at the same time; so that the nitrification of the soil with only its normal supply of organic nitrogen was tested, as well as its nitrifying power when an abundant supply of organic nitrogen was present.

In 1909 the rate of nitrification of soil from the alfalfa plats and from the timothy plats was tested by using ammonium sulfate as described above. The samples were taken to a depth of eight inches on October 6.

In Table 25, which contains the results of these tests, the quantity of nitrates produced in ten days represents the difference between the quan-

tity of nitrates when the samples were taken and the quantity at the end of ten days. The column showing the quantity of nitrates at the end of twenty days has not had the original nitrates subtracted.

TABLE 25. NITRIFICATION IN SOIL UNDER ALFALFA AND UNDER TIMOTHY

Plat	Crop	Soil treatment	Nitrates produced in ten days (parts per million)	Nitrates in soil at end of twenty days (parts per million)
4001 A	Alfalfa	Limed	176	381
4002 A	Timothy	Limed	145	361
4001 C	Alfalfa	Not limed	92	148
4002 C	Timothy	Not limed	77	148

It appears from the results here tabulated that the alfalfa soil, both when limed and when not limed, has a capacity for converting ammonia into nitric acid more quickly than does the timothy soil. This is indicated by the results at the end of ten days. At the end of twenty days, however, the crop factor did not affect the total production of nitrates, at which time there had accumulated about all the nitrates that the nitrifying organisms were capable of producing in the presence of their own products.

The character of the plants grown may therefore affect the rate of nitrification but not the limit of nitrate accumulation in the soil. The former, however, is of greater importance than the latter, as, under field conditions, nitrates are constantly being removed by plant roots or by drainage water and the supply for the growing crops depends on the rate at which nitrates are being formed.

Another test of nitrification in the soil previously under these crops was made on July 6, 1910. The samples for this test were taken from the bare strip on each plat. The results are stated in Table 26.

Nitrate formation is greater in each case in the soil which previously grew alfalfa than in the soil on which timothy had been grown.

In 1911 tests of nitrate formation in the soil under the crops and also in the bare strips on these plats were made. Samples were taken to a depth of eight inches on May 10, May 29, and November 8. In Table 27 are

TABLE 26. NITRATE FORMATION IN SOIL WHICH HAD PREVIOUSLY GROWN ALFALFA AND TIMOTHY, BUT WHICH WAS KEPT FREE FROM VEGETATION DURING THE YEAR IN WHICH TEST WAS MADE

Plat	Soil treatment	Previous crop	Nitrates produced in seven days (parts per million)
4001 A	Limed	Alfalfa	33
4002 A	Limed	Timothy	29
4001 C	Not limed	Alfalfa	26
4002 C	Not limed	Timothy	11

recorded the nitrates produced in fourteen days incubation. These figures represent the differences between the nitrates at the end of the incubation period and the nitrates in the soil as it came from the field.

TABLE 27. NITRATE FORMATION IN SOIL FROM PLATS ON WHICH ALFALFA AND TIMOTHY WERE GROWN AND FROM UNPLANTED SECTIONS OF THESE PLATS

Plat	Crop	Nitrates produced in fourteen days (parts per million)		
		May 10	May 29	November 8
4001 A, 4001 C	Alfalfa	48	59	48
4001 A, 4001 C	None	48	40	16
4002 A, 4002 C	Timothy	50	41	34
4002 A, 4002 C	None	42	33	15

Except in the first test made, the alfalfa soil showed a greater nitrate production than did the timothy soil. In every case the bare soil previously planted to alfalfa nitrified more rapidly than did the bare soil previously planted to timothy. In the test of November 8 the nitrates in the bare soil as it came from the field were so high that the increase during incuba-

tion was probably curtailed by the inhibiting action of the products of the nitrifying bacteria.

The natural inference from these results is that in some way the growth of alfalfa renders this soil capable of developing nitrates more rapidly than does the growth of timothy, and that this quality persists in the soil for at least one or two years after the crops are removed.

In addition to the incubation tests of the natural soil, further experiments were conducted by adding to 100 grams of fresh soil 100 milligrams of dried blood and incubating as before. In Table 28 appears a statement of the quantity of nitrates produced in fourteen days under these conditions, and also the excess of nitrates when the soil is incubated with dried blood over those formed by incubation of the natural soil:

TABLE 28. NITRATES PRODUCED BY INCUBATION WITH DRIED BLOOD (PARTS PER MILLION)

Plat	Crop	Nitrates produced in fourteen days		Excess of nitrates with dried blood over those with direct incubation	
		May 10	May 29	May 10	May 29
4001 A, 4001 C	Alfalfa	172	177	124	118
4001 A, 4001 C	None	196	150	148	110
4002 A, 4002 C	Timothy	133	108	83	67
4002 A, 4002 C	None	130	105	88	72

Here again there is shown to be a more active nitrate production in the alfalfa soil than in the timothy soil. The object in incorporating dried blood with the soil was to insure the presence of a large quantity of easily ammonifiable and nitrifiable nitrogen, thus making it possible to measure the activity of the ammonifying and nitrifying organisms independently of the native nitrogenous matter which might be present in larger quantity in the alfalfa than in the timothy soil. The activity of the nitrate-producing bacteria may therefore best be represented by the values obtained by subtracting the nitrates produced by direct incubation from those obtained by incubation with dried blood. The two last columns of Table

28 give these results. In both tests the nitrate-forming bacteria in the alfalfa soil are more active than are those in the timothy soil.

From these data the conclusion may be drawn that the growth of alfalfa on this soil has given rise to greater activity on the part of the nitrate-producing bacteria, or that at least it has not had so pronounced an inhibiting action as the timothy has had.

It is difficult to determine whether the effect of the alfalfa on the soil has been to increase the activity of the nitrifying bacteria as compared with the unplanted soil, or only as compared with the timothy soil. In other words, it may be the case merely that alfalfa depresses nitrification less than does timothy. One reason why it is difficult to ascertain the relative activity of the nitrifying bacteria in the planted and the unplanted soil is because nitrates are higher in the unplanted soil as it comes from the field and the increase during incubation reaches a point at which the products formed may interfere with further action.

The columns in Table 28 in which is stated the excess of nitrates when the soil was incubated with dried blood over those with direct incubation, possibly give some light on this question. It will be noticed that the planted soil produced about the same excess, in the main, as did the unplanted soil. Unfortunately, incubation with dried blood was not performed in the test made later in the season. It seems probable that the character of the organic matter left in the soil by the plants determines to some extent the rate of nitrification in this soil. This is indicated by the

TABLE 29. NITRATES PRODUCED BY INCUBATION BOTH WITH AND WITHOUT DRIED BLOOD IN UNLIMED SOIL (PARTS PER MILLION)

Plat	Crop	Nitrates produced in fourteen days				Excess of nitrates with dried blood over those with direct incubation	
		May 10		May 29			
		Incubation with natural soil	Incubation with dried blood	Incubation with natural soil	Incubation with dried blood	May 10	May 29
4001 C	Alfalfa	66	213	82	227	147	145
4001 C	None	65	206	42	193	141	151
4002 C	Timothy	56	169	47	136	113	89
4002 C	None	49	170	29	112	121	83

fact that, while with incubation of the natural soil the rate of nitrification is more rapid in the planted than in the unplanted soil, yet when nitrification is independent of the native organic matter the rate is practically the same for both the planted and the unplanted soil.

Another question that presents itself is whether the rate of nitrate formation in the unlimed soil would be in the order named. In Table 29 the quantities of nitrates produced during incubation, both with and without dried blood, are stated for the unlimed soil from the alfalfa and the timothy plats. It is seen from this table that the rate of nitrate formation is in the same order as in Table 28.

The nitrate content of alfalfa soil and of timothy soil

Determinations of nitrates in soil growing alfalfa and in soil growing timothy were made from time to time from the summer of 1906, when the seeding was done, to the autumn of 1911. In 1910 and 1911 nitrates were determined also in the unplanted sections of these plats. The nitrate content of the planted sections of the plats during the first year of growth of alfalfa and of timothy, and of both the planted and the unplanted sections during the last two years, are given in Table 30:

TABLE 30. NITRATES IN SOIL UNDER ALFALFA AND UNDER TIMOTHY, AND IN BARE SOIL PREVIOUSLY PLANTED TO THESE CROPS (PARTS PER MILLION)

Crop	1906			1910	1911			
	May 25	July 16	September 6	July 6	May 10	May 29	July 31	November 8
Alfalfa	37	23	11	21	11	10	8	5
None	......	......	......	42	39	65	121	145
Timothy	31	21	8	4	4	6	1	3
None	......	......	......	21	18	32	50	129

It may be seen in Table 30 that the nitrates under timothy are somewhat lower than under alfalfa, but that the difference is not great especially when compared with the nitrates in the unplanted soil. The indications are, therefore, that alfalfa either absorbs nitrates from the soil or depresses nitrate formation to a very great extent. If, however, the nitrates under alfalfa are compared with those in the bare soil previously planted to

alfalfa, and then the nitrates under timothy are compared with those in the bare soil previously planted to timothy, it is evident that the nitrates are relatively much lower under alfalfa. As the nitrates in the unplanted soil represent the available nitrates for each crop, it is apparent that alfalfa either has a much greater effect than has timothy in inhibiting nitrate formation or is using more nitrates than is timothy. But it has been shown previously that alfalfa has a stimulating effect on nitrate formation as compared with timothy. It must be concluded, therefore, that, under similar conditions, alfalfa on this soil is absorbing more nitrates than is timothy.

Since there was some doubt in regard to the relation that these two crops may have to the nitrate content of the soil below the surface foot — especially as alfalfa is a much deeper-rooting plant than timothy — the soil was sampled on July 6, 1910, to a depth of four feet and the samples from each foot were analyzed separately. The same number of borings were taken for these analyses as for the others. Both the planted and the unplanted sections of the plats were sampled. The results of the analyses are given in Table 31.

It is seen from this table that the depths below the surface foot contain very small quantities of nitrates under both crops, and even in the unplanted soil the nitrates below the first foot do not change the relations that exist in the surface soil. The samples were taken in midsummer, when the nitrates would have had ample opportunity to leach into the lower soil; they were obtained five years after the crops were planted, during which time the alfalfa roots had penetrated much beyond the upper four feet of soil. It may safely be assumed that the nitrates in the first foot of soil under these crops give an adequate conception of the relative nitrate content of both crops.

Nitrifying activity of soil under crops as shown by inoculation tests

Further experiments were conducted with maize, oats, and bare soil, in which the nitrifying activity of the soil from a number of the plats was maintained at a temperature favorable for nitrification and at an optimum moisture content for a number of days, both when dried blood was added to the soil and when the soil was untreated. The object in adding dried blood was to have in the soil an abundance of easily ammonifiable and nitrifiable organic matter and thus eliminate the errors that might arise

TABLE 31. NITRATES IN SOIL UNDER ALFALFA AND UNDER TIMOTHY, AND IN SOIL THAT HAD PREVIOUSLY GROWN THESE CROPS BUT THAT WAS KEPT FREE FROM VEGETATION. SAMPLES TAKEN JULY 6, 1910

Plat	Depth (feet)	Crop on soil when sampled			Bare soil	
		Crop	Soil treatment	Nitrates (parts per million)	Previous crop	Nitrates (parts per million)
4001 a...	1	Alfalfa.......	Limed.......	14	Alfalfa.......	46
4001 a...	2	Alfalfa.......	Limed.......	1	Alfalfa.......	7
4001 a...	3	Alfalfa.......	Limed.......	1	Alfalfa.......	5
4001 a...	4	Alfalfa.......	Limed.......	1	Alfalfa.......	3
Total...	....	....	....	17	....	61
4002 a...	1	Timothy.....	Limed.......	6	Timothy.....	30
4002 a...	2	Timothy.....	Limed.......	1	Timothy.....	3
4002 a...	3	Timothy.....	Limed.......	1	Timothy.....	3
4002 a...	4	Timothy.....	Limed.......	1	Timothy.....	Trace
Total...	....	....	....	9	....	36
4001 c...	1	Alfalfa.......	Not limed....	28	Alfalfa.......	39
4001 c...	2	Alfalfa.......	Not limed....	3	Alfalfa.......	14
4001 c...	3	Alfalfa.......	Not limed....	2	Alfalfa.......	3
4001 c...	4	Alfalfa.......	Not limed....	Trace	Alfalfa.......	1
Total...	....	....	....	33	....	57
4002 c...	1	Timothy.....	Not limed....	3	Timothy.....	12
4002 c...	2	Timothy.....	Not limed....	Trace	Timothy.....	3
4002 c...	3	Timothy.....	Not limed....	Trace	Timothy.....	Trace
4002 c...	4	Timothy.....	Not limed....	Trace	Timothy.....	Trace
Total...	....	....	....	3	....	15

through differences in the soil in this respect. The nitrate content of the soil as it came from the field was then subtracted from the nitrate content after incubation without dried blood, in order to ascertain the nitrifying activity of the soil. The nitrates formed in the soil treated with dried blood less the nitrates in the field soil possibly represent the efficiency of the nitrate-forming bacteria more nearly than do the nitrates produced either by direct incubation or by incubation with dried blood. In Table

32 these values are given, and also the figures for the nitrates formed by incubation with dried blood less those formed by direct incubation, which probably also represent the efficiency of the nitrate-forming bacteria.

The method used in measuring the nitrate-forming activity of the soil was as follows: The soil was sampled by means of a soil auger to a depth of eight inches. The borings from the plat or section of plat to be tested were mixed, quartered, and placed in an air-tight jar while still moist. When the jar was brought to the laboratory, moisture and nitrates were determined within twelve hours after sampling. Nitrates were determined in 100 grams of moist soil by means of the disulfonic-acid method. Another 100 grams of moist soil was placed in a bottle having a capacity of 250 cubic centimeters, and sufficient water was added to bring the moisture content to 25 per cent of the dry weight of the soil. A loose cotton plug was inserted into the mouth of the bottle, which was then placed in an incubator and kept at a temperature of 30° C. and at a constant moisture content for fourteen days, at the end of which time nitrates were determined. Tests were made also by adding 100 milligrams of dried blood to 100 grams of fresh soil and incubating as above. The samples of soil for tests with dried blood and those for tests without dried blood were weighed out at the same time, so that the conditions of the test were similar except for the addition of the dried blood.

TABLE 32. NITRATE FORMATION IN PLANTED AND UNPLANTED SOIL INCUBATED WITH AND WITHOUT DRIED BLOOD, IN 1911 (PARTS PER MILLION)

Plat	Crop and treatment	Nitrates in natural soil less field nitrates			Nitrates in soil plus dried blood, less field nitrates		Nitrates in soil plus dried blood, less nitrates from incubation with natural soil		
		June 16	July 10	October 9	June 16	July 10	June 16	July 10	August 4
2201, 2209 2401, 2409	Maize, mulched	32	46	26	110	142	78	96	......
2201, 2209 2401, 2409	None	33	37	26	126	125	93	88	......
2203, 2211 2403, 2411	Maize, cultivated	40	56	30	119	141	79	85	......
2203, 2211 2403, 2411	None	39	45	32	139	127	100	82	......
2207, 2215 2407, 2415	Oats	46	40	30	105	115	59	75	51
2207, 2215 2407, 2415	None	57	37	39	118	111	61	74	50

Considering first the nitrates formed by incubation of the natural, or untreated, soil, it will be seen that on June 16 the maize-planted and the bare soil showed approximately equal nitrate formation. At this time the maize was about eight inches high. On the same date the soil from the oats, which were about a foot high, gave less nitrate formation in the planted than in the unplanted soil. On July 10 both the maize and the oat soil produced more nitrates than did the bare soil. The maize soil was particularly active in this respect. On October 9 nitrate formation was less in the planted than in the unplanted soil. On July 10 the maize had not yet started to tassel and the oats were in a late stage of bloom. On October 9 growth had ceased.

Incubation with dried blood on June 16 shows less nitrate formation in the planted than in the unplanted soil of both crops. The incubations of July 10 show more nitrate formation in the planted soil, for both maize and oats. With an abundant supply of organic nitrogen the nitrate-forming bacteria were very active in the planted soil at this stage of growth, which is an active stage for both these plants. These results are in line with the results obtained by determinations of nitrates in the field; in those tests it was sometimes found that during the active stages of growth the nitrates in the maize soil were higher than those in the corresponding unplanted soil. Nitrates under oats in the field were never so high as in the bare soil. It was concluded from analyses of the field samples that, while the oat plant probably stimulates the formation of nitrates during some stages of its growth, the effect which it exerts in this way is not so great as that produced by the maize plant. The results obtained by these incubation tests show a greater nitrate production in the maize soil than in the oat soil.

There is one essential difference between nitrate formation in the field soil and in the soil brought to the laboratory and placed in the incubator: the latter soil is thoroughly aerated, and some conditions favorable or inimical to nitrate formation may be dispelled.

On October 9 incubation tests were made only with the natural soil. Nitrate production on that date was less in the planted soil. This is again in line with the results obtained from field samples, in which the nitrate content was always very low under a crop during the later stages of growth or after maturing. The incubation tests show a markedly depressing influence for the oat crop and a slight depression for the maize crop. The

depressing effect of the oat crop on nitrate formation was shown, by other experiments, to be carried over to the succeeding year, when land previously in maize contained uniformly a higher nitrate content than did land previously in oats.

The depressing influence of the plant is thus shown to be an indirect one, and to remain with the soil for a considerable length of time. Neither influence is completely nullified by aeration, at least by such aeration as is involved in the process of sampling the soil and transferring it to bottles for incubation, although this operation necessitates a very thorough stirring of the soil. It is altogether probable, however, that the depressing influence is decreased by this process. It is much more marked in field tests than in incubation tests; but the former always involve the removal of nitrates by the crop, which introduces an unknown factor. Data will be presented later, showing that freezing dispels in part the depressing effect of the plant on nitrate formation.

Formation of nitrates in soil after freezing and thawing

It has been suggested by the writers that plants which mature on the soil have a depressing effect on nitrate formation in that soil for some time afterwards. If this is the case, it seems probable that the inhibiting effect of the crop may be removed in greater or less degree by subjecting the soil to certain treatments. The effect of aeration on formation of nitrates is well known. To what extent freezing may affect the nitrifying property of a soil is not so well understood, as few experiments on that subject have been published.

Recently Brown and Smith (1912) reported that in ammonification tests in peptone solutions and in soil to which infusions of field soil were added at intervals from October 17 to March 1, the ammonifying power was greater after the soil had become frozen than before. Similar tests of the nitrifying power of the field soil did not indicate an increase in the nitrifying power of the frozen soil, but these investigators did not consider their results in this experiment conclusive. Four pots of soil that had been in the greenhouse for a year and had raised a crop of wheat and a crop of millet during that time were used in the experiment. Pots 127 and 128 contained the same kind of soil and had received the same treatment, and pots 343 and 344 corresponded with each other in these respects. The

two first-mentioned pots contained Volusia silt loam and the other two contained Dunkirk clay loam.

On December 28, 1911, pots 127 and 343 were placed in a building in which the temperature corresponded closely with that of the outside air but the moisture content of the soil could be controlled. Pots 128 and 344 remained in the greenhouse. All the pots were kept bare of vegetation and were maintained at a moisture content of about 25 per cent of the dry weight of the soil. On February 28, 1912, pots 127 and 343 were returned to the greenhouse. During most of the time that they were in the outside building they were frozen, and two or three times they thawed. They stood in the greenhouse with pots 128 and 344 until March 4, when all were brought to the laboratory and nitrates were determined. The results are shown in Table 33:

TABLE 33. NITRATES IN SOILS SUBJECTED TO FREEZING AND IN SIMILAR SOILS REMAINING UNFROZEN

Pot	Kind of soil	Treatment	Nitrates (parts per million)
127	Volusia silt loam	Frozen	155
128	Volusia silt loam	Unfrozen	112
343	Dunkirk clay loam	Frozen	92
344	Dunkirk clay loam	Unfrozen	70

It would appear from this table that freezing produces a condition of soil favorable for nitrate formation. The well-known action of frost in producing a granular condition of a clay soil may have operated to some extent to bring about this condition. To what extent the more active production of nitrates is due to aeration and to what extent it is due to cold, it is impossible to say; but the obvious effect is to overcome the depressing influence of the crop previously grown and to permit the resumption of nitrate formation required for the growth of the crop that follows.

The depressing influence of grass on nitrate formation a possible factor in orchard management

The experiments by Dehérain and by Leather, already cited, indicate that all the plants tested except maize depressed the formation of nitrates

to such an extent that the nitrogen in the crop plus that in the drainage water was less than the nitrogen in the drainage water from an unplanted lysimeter containing a similar soil. These results are in part confirmed by experiments conducted by the writers with somewhat similar apparatus. The writers have had only two years in which to use this set of tanks, and hence the data are probably not entirely reliable.

Experiments were conducted in large concrete tanks filled with soil. The tanks are four feet two inches square and four feet deep and each tank holds about three and one half tons of soil. The soil used was from the experiment field in which most of the other experiments with nitrate formation were conducted. The tank soil receives the natural rainfall and no other water supply. The drainage water is all collected and measured and samples are taken for analysis. In 1910 four tanks were planted to maize, two were planted to oats, and three remained unplanted. In 1911 four tanks were in oats, two were in grass, and two were bare of vegetation. The unplanted tanks were cultivated in 1910, and in 1911 they were scraped in order to remove weeds without stirring.

In Table 34 are given the quantities of nitrogen in the drainage water, and in the crop, including the estimated quantities in the roots, for the periods already stated.

The results do not agree in every respect with those obtained by Leather and by Dehérain. Both the tanks planted with maize and those planted with oats contained a larger quantity of nitrogen in the crop and the drainage water combined than the unplanted tanks contained in the drainage water. The grass-planted tanks, like those of the experimenters just cited, contained notably less. In fact, less than two thirds as much nitrogen was found in the combined crops and drainage from the grass tanks as was found in drainage from the bare tanks.

The quantity of nitrogen removed by the crop and the drainage water combined is in the same order with respect to the kind of plant grown as is the nitrate content of the soil, as shown by the plat experiments. Thus, the nitrogen removed from the maize plats was greatest, that from the oats plats was next, and that from the grass plats was least; and the nitrate content of the maize soil is higher during the growing season than is that of oats, and the latter soil has uniformly a higher nitrate content than has grass land. These results are shown graphically in Diagram XXV.

TABLE 34. REMOVAL OF NITROGEN FROM PLANTED AND UNPLANTED SOIL TANKS

(May 23, 1910, to May 1, 1911)

Tanks	Crop	Nitrogen (pounds per acre) in			
		Drainage	Tops	Roots* (estimated)	Tops, roots, and drainage
2, 4, 8	None	120	....	....	120
3, 5, 7, 9	Maize	11	140	47	198
6, 10	Oats	12	90	30	132

(May 1, 1911, to May 1, 1912)

Tanks	Crop	Nitrogen (pounds per acre) in			
		Drainage	Tops	Roots* (estimated)	Tops, roots, and drainage
4, 8	None	68	....	....	68
3, 5, 7, 9	Oats	5	52	17	74
6, 10	Grass	1	30	10	41

* Nitrogen in roots estimated as one third that in tops.

If plants have a stimulating influence on nitrate formation during the earlier growing stages and a depressing influence later, the nitrogen in the drainage water plus the nitrogen in the crop will be greater or less than the nitrogen in the drainage water from the unplanted soil, in proportion to the relative activities of the two influences and also to the extent to which the plant in question absorbs nitrogen in forms other than as nitrates.

In Dehérain's experiments maize gave about as much nitrogen in the crop and the drainage water as was contained in the drainage water of the

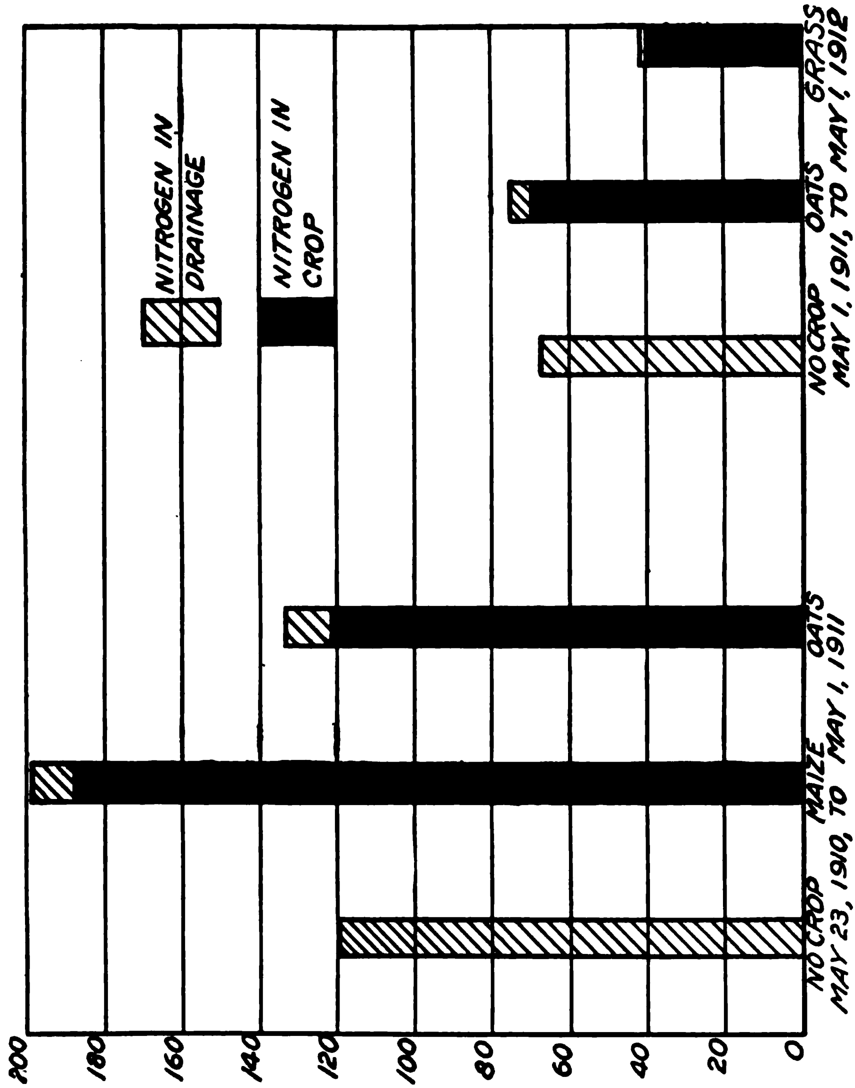

DIAGRAM XXV.— *Number of pounds of nitrogen removed per acre from planted and unplanted soil tanks*

uncropped soil; in the writers' experiments maize soil afforded a much larger quantity of nitrogen in the crop and drainage. Oats also, in the writers' experiments, accumulated more nitrogen in the crop and drainage water than was contained in the water from the bare soil. Grass, however, gave results of a nature similar to those obtained by Dehérain, but in less degree.

It is evident that in the case of grass the depressing influence on nitrate formation is greater than the stimulating influence.

The discrepancy between the writers' results and those obtained by Dehérain and by Leather may be accounted for in any one or more of the following ways:

1. On the soil used by the writers the plants may have absorbed a larger proportion of their nitrogen in forms other than as nitrates.

2. Possibly the very heavy clay soil used in the writers' experiments retained a larger proportion of nitrates, and this would have affected the bare soil more than it would the planted soil as the quantity of nitrates in the former was much greater than that in the latter.

3. The lower layers of the soil may have been the scene of a denitrifying process, which would probably have decreased the nitrogen removed from the bare soil more than that from the planted soil because there were more nitrates in the bare soil to be denitrified.

4. The stimulating influence of the higher plants on nitrate formation may have been greater in comparison with the depressing influence in the soil used by the writers than in the soils used by Dehérain and Leather.

The evidence afforded by the experiments of Dehérain and Leather indicates that wheat, oats, potatoes, grass, and beets have a greater depressing influence than they have stimulating influence on nitrate formation, and that the stimulating and the depressing influence in maize practically balance each other. The high nitrate content in maize soil on the writers' experiment field in the spring following the growth of the maize crop, as well as the results from the soil tanks, indicates that on this soil the stimulating influence of maize is greater than its depressing influence.

It appears from these considerations that the three kinds of plants grown in the tanks at this station exerted a greater stimulating influence on nitrate formation than did the same plants at Grignon, and that the extent to which higher plants affect nitrate formation favorably or unfavorably varies in different soils. The soil used by the writers is evidently very favorable to nitrate formation.

That grass exercises a strongly depressing action on nitrate formation is indicated not only by the three sets of tank experiments cited above, but also by the determinations of nitrates under timothy sod previously presented in this paper. This characteristic of the grasses almost completely prevents a loss of nitrogen in the soil drainage and thus tends to conserve nitrogen, which is doubtless one of the factors in the accumulation of nitrogen in grassland.

The same properties of grass with respect to nitrate formation may be a factor in the effect of grass in orchards.

Stewart (1911) has lately called attention to the need of nitrogen in orchard fertilization. Experiments indicate that under some conditions the use of nitrate fertilizer has been very effective in increasing the growth and yield of apple trees. In sod-covered orchard soil the supply of nitrates must be kept very meager by the grass, and if the other forms of nitrogen in the soil are not such as to afford a suitable supply the trees must suffer from lack of nitrogen. Where trees apparently thrive on sod, a part of their nitrogen supply may come from some nitrogenous compounds other than nitrates.

The plants used as cover-crops doubtless exercise an influence in this respect. The practice of fallowing an orchard until July and then planting a cover-crop is in accordance with the most economical management of the soil nitrogen. In this way the formation of nitrates is favored during the early part of the summer, and is depressed when the supply is no longer needed by the trees and would otherwise be leached from the soil. This is, of course, assuming that nitrates are utilized by apple trees as a source of nitrogen.

The influence of a preceding crop on nitrate formation in soil

While the practices of crop rotation have been fairly well worked out, there yet remains much to learn regarding the underlying principles. Most of the effort in experimentation with soils has been made with a view to ascertain the effect of certain soil conditions on plant growth or on the solubility of the mineral nutrients in various solvents. The study of the principles of crop rotation necessitates the investigation of the effect of plant growth on the soil. The fact that a certain plant grows better when preceded by one species of plant than when preceded by another is a self-evident indication that plants of different species exert different influences on the soil.

The writers have already suggested that certain higher plants have a distinct influence on the process of nitrification in the soil, and that this influence varies in intensity with plants of different families and at different stages in the growth of any one kind of plant. It was found, for instance, that in a soil on which maize was growing the nitrates were sometimes higher at certain periods than in a similar soil on which no plants grew. Timothy (*Phleum pratense*), on the other hand, maintained uniformly a very low nitrate content in the soil throughout the growing period.

The question then arose whether the higher plants exert any influence on the activities of the nitrifying bacteria after the plants are removed. In order to test this it was decided to continue the nitrate determinations for a second year, in soil that had been planted to several kinds of crops.

Plats that had been used in 1910 for studying the effect of plants on the nitrate content of soils were left bare in 1911 until July 1. In order to keep down weeds the plats were disk-harrowed from time to time. Samples of soil were taken from the sections of the plats that were planted and those that were bare in 1910, for the purpose of ascertaining the effect on the nitrate content of the soil of the different crops grown in the previous year. The borings were made to a depth of eight inches below the surface, and from eight to sixteen inches below the surface. In Table 35 are presented the results averaged for the entire season for the four plats planted to the same crop, also the averages of the unplanted sections of the same plats during the growing season of 1910. The table consequently shows the nitrate content of the soil in the year during which the test crops were grown.

TABLE 35. NITRATES IN PLANTED AND UNPLANTED SECTIONS OF PLATS. AVERAGE FOR THE GROWING SEASON, 1910

Plat	Crop	Nitrates (parts per million)	On basis of nitrates in unplanted soil taken as 100	Nitrogen in crop (pounds per acre)
3612, 3613, 3622, 3623	Maize	167	123	3
	None	136	100	...
3614, 3615, 3624, 3625	Potatoes	104	96	43
	None	108	100	...
3616, 3617, 3626, 3627	Oats	90	71	29
	None	126	100	...

The nitrates were highest under the maize, next highest under the potatoes, and lowest under the oats. Similar results had been obtained in previous years.

The last column of Table 35 shows the quantity of nitrogen removed per acre by each crop. The maize crop was a very poor one, which accounts for the small quantity of nitrogen contained in that crop. It is doubtless true that the small maize crop is partially responsible for the high nitrate content of the maize soil; however, this high nitrate content has been found in maize soil in previous years when the crop was good. Again, the persistently higher nitrate content of the maize soil as compared with the unplanted soil can be explained only on the assumption that nitrate formation is much more active where the maize is growing, for certainly more nitrates are being removed from the planted soil.

Nitrates are higher in the potato soil than in the oat soil, although the former crop removed nearly fifty per cent more nitrogen than did the latter. The nitrate content of a planted soil is not determined by the total quantity of nitrogen removed by the crop, but by a number of factors, of which one appears to be a direct influence which each species of plant exerts on the activity of the nitrifying organisms.

In the year following that in which the results given above were obtained, these plats were kept free from vegetation until July 1 and nitrates were determined from time to time. In Table 36 is given a statement of the nitrates in the previously planted and in the unplanted sections of these plats, on each of the dates when the soils were analyzed:

TABLE 36. NITRATES IN SOIL PLANTED IN THE PREVIOUS YEAR AND UNPLANTED IN 1911

Plat	Crop	May 1		June 5		June 28	
		Surface eight inches	Second eight inches	Surface eight inches	Second eight inches	Surface eight inches	Second eight inches
3612, 3613, 3622, 3623	Maize....	51	53	78	45	40	34
	None....	48	52	68	44	40	30
3614, 3615, 3624, 3625	Potatoes..	31	26	50	26	29	24
	None....	43	43	80	43	85	29
3616, 3617, 3626, 3627	Oats.....	23	21	41	33	22	22
	None....	32	40	68	35	34	32

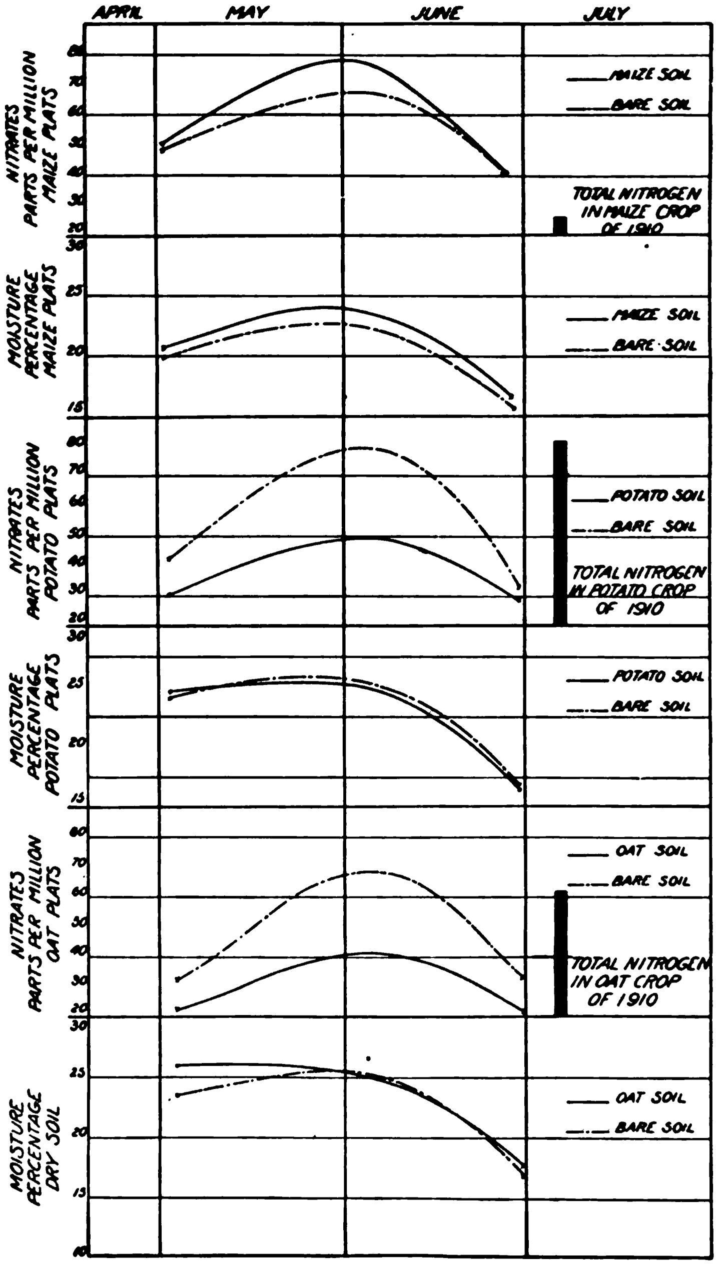

DIAGRAM XXVI.— *Nitrates and moisture in surface eight inches of soil plats kept bare of vegetation in 1911, which had been planted in 1910 to maize, potatoes, and oats with bare sections on each plat*

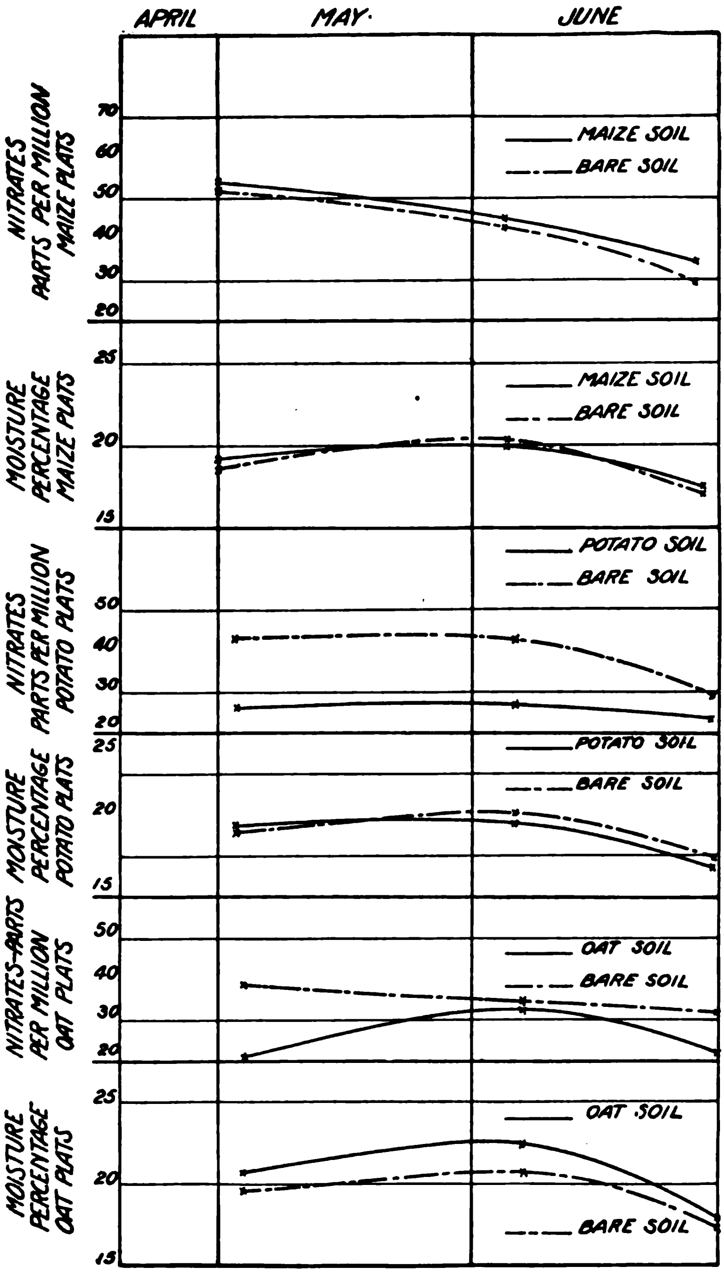

DIAGRAM XXVII.— *Nitrates and moisture in second eight inches of soil plats kept bare of vegetation in 1911, which had been planted in 1910 to maize, potatoes, and oats with bare sections on each plat*

An examination of this table shows that, except in the case of maize, the nitrates are lower in the soil on which plants grew during the previous year than in the soil kept unplanted during that time. It will be noticed also that the nitrates on the unplanted soil are in the same order as they were when the plats were planted. Thus, nitrates are highest in the soil previously planted to maize, next in that planted to potatoes, and lowest in that planted to oats. This is brought out also in diagrams XXVI and XXVII.

In Table 37 is given a statement of the nitrates in the planted sections of the plats in terms of the nitrates in the unplanted sections taken as 100. In order to obtain these figures the nitrates in both planted ends of each of the four plats planted to the same crop are averaged, and this average is divided by the average for the nitrates on the unplanted sections of the corresponding plats. This furnishes the most convenient means of comparison, as it removes more effectively than any other method the local variations in the nitrate content of the soil.

TABLE 37. RATIO OF NITRATES IN SOIL OF PLATS PREVIOUSLY PLANTED TO NITRATES IN UNPLANTED SOIL

Plat	Crop	Surface eight inches			Second eight inches		
		May 1	June 5	June 28	May 1	June 5	June 28
3612, 3613, 3622, 3623	Maize.....	106	115	100	102	102	113
3614, 3615, 3624, 3625	Potatoes...	72	62	83	60	60	83
3616, 3617, 3626, 3627	Oats.....	72	60	65	52	94	69

There is a distinct and characteristic difference in the nitrate content of the soil previously bearing these different plants. While the experiment covers only one season, the differences would seem to be too large and too well-defined to be accidental.

On July 1 the plats used in this experiment were drilled to millet. The entire plats were planted, including the middle section of each plat which during the preceding year had remained unplanted. The object in planting millet was to ascertain how the growth of a crop on these plats would correspond with the nitrate content.

On September 8 careful notes were taken of the growth on each plat, and a comparison was made not only between different plats but also between the growth of millet on the previously planted sections and on the unplanted section of each plat.

In each plat the growth of millet was markedly better on the sections that had been in crop during the previous year than on the unplanted section. This applied to every crop in the experiment. A comparison of the growth on the planted sections of the plats is given in Table 38, in which the growth of millet on the plats planted to oats is taken as 100 and the growth on the other plats is stated on this basis:

TABLE 38. GROWTH OF MILLET ON PLATS PLANTED TO DIFFERENT CROPS IN THE PRECEDING YEAR

	Soil treatment	Plat	Growth of millet (percentage)	Plat	Growth of millet (percentage)	Average growth of millet (percentage)
Maize	Not limed	3612	37	3622	62	49
	Limed	3613	47	3623	71	59
Potatoes	Not limed	3614	60	3624	81	70
	Limed	3615	65	3625	88	76
Oats	Not limed	3616	100	3626	100	100
	Limed	3617	100	3627	100	100

It will be seen that the luxuriance of the growth of millet on these plats was inversely proportional to the relative concentration of nitrates in the soil. For instance, the millet made the best growth on the plats planted to oats, and these plats had the lowest nitrate content. The poorest growth of millet was on the maize plats, and these had the highest concentration of nitrates.

In Table 39 the relative nitrate content in the surface eight inches of the several plats on June 28, which was only a few days before the millet was planted, is compared with the percentage growth of millet on the same plats:

TABLE 39. COMPARISON OF NITRATES IN SOIL PLANTED TO CERTAIN CROPS WITH GROWTH OF MILLET ON THE SAME PLATS

Crop in 1910	Relative nitrate content	Relative growth of millet
Oats	55	100
Potatoes	70	73
Maize	100	54

It would seem from these results that in this soil the conditions favoring the growth of millet were unfavorable to the formation of nitrates. That this is not true of all conditions is evident from the fact that the millet grew better on the limed than on the unlimed soil, as shown in Table 38; while the nitrates also are higher in the limed plats, as may be observed in Table 40, which follows:

TABLE 40. NITRATES IN UNPLANTED SECTIONS OF PLATS LIMED AND NOT LIMED

Plat	Soil treatment	Nitrates (parts per million)			
		May 4	June 5	June 28	Average
3612, 3622	Not limed	40	61	42	48
3613, 3623	Limed	55	75	39	56
3614, 3624	Not limed	40	77	34	50
3615, 3625	Limed	45	82	36	54
3616, 3626	Not limed	28	52	36	39
3617, 3627	Limed	36	85	40	54

It is evident that, although the previous crop influences greatly the nitrate content of this soil, the growth of millet is not increased thereby. Nitrates are not the limiting factor in the growth of millet on this soil.

Lime increases the growth of millet and also the formation of nitrates, but apparently its beneficial action on the growth of millet must be due to some cause other than its influence on nitrate formation.

The purpose of this experiment is to ascertain the influence of certain kinds of plants on the formation of nitrates in the soil after the crops have been removed. The relation of the nitrate formation to the growth of millet on this soil is a separate problem, probably peculiar to this particular soil but possibly worth recording. The interesting condition exists that, of the crops used in the experiment, each had a certain and distinct influence on nitrate formation following the removal of the crops and on the growth of millet also following their removal, but a high nitrate content was not necessarily accompanied by a large crop of millet. It is not to be expected, however, that this lack of correlation will obtain in all soils, since under some circumstances the presence of an abundance of nitrates will throw the influence toward a better growth of the succeeding crop. There is thus presented a problem in crop rotation. If the influence of a certain kind of plant on the formation of nitrates after its removal holds for soils other than the soil used in this experiment, something has been learned. That other influences obtain, and, under some circumstances, influences more potent than nitrate formation, is also indicated by this experiment.

Is there a mutual stimulation of plant growth through root influence?

The stimulating influence of plant growth at certain stages on nitrate formation in soils suggested a possible benefit to higher plants from other and younger plants growing with them. It was decided to start a number of plants of different kinds in the greenhouse, placing them far enough apart to prevent interference, at least while they were young, and after they had attained a reasonable size to sow between them seed of a different kind of plant in order to ascertain whether the plants that were first started received any benefit from the growth of the plants seeded later. If the later-started plants stimulated nitrate formation at a time when the earlier-started plants were beginning to depress it, the latter might receive some benefit from the nitrates formed.

In order to test this question, an ordinary greenhouse bench was divided into compartments eighteen inches square and six inches deep. These were filled with soil of good quality, prepared by rotting timothy sod which had been produced on Dunkirk clay-loam soil. About twenty-five or thirty of the earlier-started plants were grown at equal distances apart in each square. These will be designated as the " primary " plants or crop. Twice as many plants were started later, being arranged one on each side

of the primary plants. These will be termed the "secondary" plants or crop. In some cases the secondary plants were planted at the same time as the primary.

For the purpose of checking the experiments in which soil was used for growing plants, a series of tests were made with crushed quartz containing about thirty per cent of its weight of nutrient solution. This solution had a density of 4500 parts per million.

Glazed earthenware pots of a capacity of one half gallon were filled with the quartz and the nutrient solution, and four to twelve plants, depending on the size, were grown as a primary crop in each pot. The secondary crop consisted of twice as many plants. The moisture content was maintained by weighing the pots two or three times a week and adding distilled water in sufficient quantity to make up the loss. Nutrient solution was added two or three times in the life of the plants. It was intended to have an abundant supply of plant nutrients, especially nitrogen in the form of nitrate. The object in using the nutrient solution was to furnish a medium in which the secondary crop could be of no assistance as a means of supplying nitrate nitrogen.

In both the soil and the crushed quartz, the squares and the pots planted with the primary and the secondary crops were in each case accompanied by similar receptacles planted with the primary crop alone and containing exactly the same number of plants as were present as a primary crop in the vessels containing the primary and the secondary, or what will be termed the mixed, crops. The yields of the plants growing alone may thus be compared with the yields of the primary plants in the mixed crops, as a measure of the effect of the secondary crop on the primary crop.

The plants growing in the mixtures were always at a disadvantage because there were always three times as many plants in the mixed crop as in the single one. In order to offset this it was intended to furnish an abundant supply of nutriment, but in the greenhouse soil this was probably not fully accomplished. In the nutrient solution some of the mixed crops possibly lacked nutriment.

The tests in the greenhouse soil in which the primary and the secondary plants were started at the same time did not give very satisfactory results, as the secondary crops grew so large that they perceptibly dwarfed the primary crops except in a few cases. This, however, was anticipated, and such mixtures were used only as checks. In the quartz cultures the pri-

mary and the secondary crops were all planted at the same time, in spite of which the secondary crops did not suffer greatly from the competition.

In Table 41 are given the yields of the primary crops in the mixtures as compared with the yields of the same crops in the single cultures when the latter are taken as 100. In this comparison the same number of plants is taken in both the single and the mixed cultures. In some cases the secondary crop grew fairly well and in other cases the growth was slight. The relative yields of the primary crop and the secondary crop in the same squares are stated in the table. The yields are based on weights of the water-free material.

TABLE 41. RELATIVE YIELDS OF PRIMARY CROPS GROWN ALONE AND OF PRIMARY CROPS IN MIXTURES ON GREENHOUSE SOIL

Primary crop	Secondary crop	Yield of primary crop grown in mixture when primary crop alone is taken as 100	Yield of secondary crop when primary crop in mixture is taken as 100	Period of growth of primary crop (days)	Period between planting primary and secondary crops (days)
Dandelion	Timothy	102	20	166	91
Timothy	Mustard	127	13	128	67
Wheat	Mustard	93	0	146	72
Oats	Mustard	132	1	142	72
Oats	Mustard	98	1	87	46
Oats	Maize	133	1	107	72
Oats	Maize	107	1	93	58
Wheat	Maize	97	1	93	61
Millet	Maize	98	17	63	44
Millet	Maize	88	8	84	65
Spring wheat	Winter oats	69	2	151	71
Spring oats	Winter oats	92	2	151	70
Peas	Lettuce	100	40	67	37
Timothy	Redtop	99	15	130	29
Wheat	Rye	112	1	84	49

It is seen from this table that in some instances the yield of the primary crop in the mixture was as large as, or larger than, when grown alone. As this occurs in nearly half of the cases, it appears at first glance that the larger yields are accidental and not due to any influence exerted by the secondary crop. Taken by themselves these results could not be said to indicate anything, although the fact that nearly half of the tests gave

larger yields of the primary crops when grown in mixtures than when grown alone is perhaps deserving of attention, especially since in the squares containing mixtures seventy-five plants were grown in six inches of soil eighteen inches square, and consequently there must have been more competition for food in the mixtures than in the pure cultures.

The cultures in ground quartz emphasize this more strongly, as may be seen in Table 42:

TABLE 42. RELATIVE YIELDS OF PRIMARY CROPS GROWN ALONE AND OF PRIMARY CROPS IN MIXTURES IN NUTRIENT SOLUTION IN CRUSHED QUARTZ

Primary crop	Secondary crop	Yield of primary crop grown in mixture when primary crop alone is taken as 100	Yield of secondary crop when primary crop in mixture is taken as 100	Period of growth of plants (days)
Wheat	Mustard	132	34	87
Wheat	Mustard	126	20	87
Wheat	Mustard	106	89	51
Wheat	Mustard	108	100	51
Oats	Mustard	133	19	87
Oats	Mustard	96	73	48
Oats	Mustard	98	99	48
Peas	Lettuce	87	15	83
Peas	Lettuce	76	8	83
Peas	Lettuce	86	8	54
Peas	Lettuce	91	3	54
Timothy	Blue grass	95	50	94
Timothy	Blue grass	78	72	94
Timothy	Blue grass	84	19	67
Timothy	Blue grass	73	26	67
Timothy	Red clover	152	38	94
Timothy	Red clover	116	44	94
Timothy	Red clover	76	180	67
Timothy	Red clover	81	146	67
Red clover	Timothy	123	26	94
Red clover	Timothy	109	44	94
Timothy	Daisy	107	36	93
Timothy	Daisy	124	47	93
Wheat	Red clover	95	20	71
Wheat	Red clover	105	27	71
Wheat	Red clover	96	4	60
Wheat	Red clover	109	5	60
Wheat	Timothy	100	5	59
Wheat	Timothy	111	7	59
Oats	Timothy	102	6	59
Oats	Timothy	75	11	59

In these tests the primary and the secondary crops were planted at the same time. The growth was more rapid than in the soil. Again in about half of the tests the primary crop gave larger yields when grown in the mixture than when grown alone. As any benefit to the primary crop by a stimulation of nitrate formation through the growth of the secondary crop is precluded by the fact that the entire supply of nitrogen was in the form of nitrate, the evidence is opposed to the supposition that any increased growth of the primary crop in the mixtures grown in soil was due to such a process.

An examination of the data recorded reveals two conditions that influence the growth of the primary crop in mixtures. These are the length of the period of growth and the relative growth of the secondary crop. The benefit to the primary crop from a longer period of growth may be due either to a slower growth or to harvesting at a later period of development of the plant. It will be noticed that for any given mixture a very large growth of the secondary crop is usually accompanied by a relatively smaller growth of the primary crop. This holds true only when the yield of the secondary crop is very large, and is presumably due to the competition of the plants for food and water.

It was decided to repeat these tests in the field, where there would be a large body of soil from which the plants could obtain nourishment and where the conditions would be more nearly normal than in the greenhouse. The plants were grown in squares six feet each way and usually twenty-five primary plants were placed in each square. Whether grown alone or in a mixture, the number of primary and secondary plants in each square was the same. The plants were not watered artificially, and as the summer was a very dry one they suffered from lack of moisture. Each combination of plants was repeated on four squares. Two of these were harvested at or near the flowering stage and the other two were allowed to ripen fully. In Table 43 the yields are given for only the squares that were harvested before the plants were mature, as in almost all cases the mature plants yielded more in single cultures than in combination. This may have been due to the severe drought or it may be the natural result under any conditions. At least it is what would have been expected. The relative yields are based on the oven-dry weights of the plants. In choosing the plants for this experiment, combinations were used which previous experience or observation indicated would give larger yields

of the primary plants when grown in combination than when grown alone. The field soil used was Dunkirk clay loam.

TABLE 43. RELATIVE YIELDS OF PRIMARY CROPS GROWN ALONE AND OF PRIMARY CROPS GROWN IN MIXTURES ON FIELD SOIL

Primary crop	Secondary crop	Yield of primary crop grown in mixture when primary crop alone is taken as 100	Yield of secondary crop when primary crop in mixture is taken as 100	Period of growth of primary crop (days)	Period between planting primary and secondary crops (days)
Barley	Buckwheat	166	37	67	30
Barley	Buckwheat	126	79	70	30
Oats	Buckwheat	132	35	70	31
Oats	Buckwheat	106	55	73	31
Oats	Mustard	115	37	70	27
Oats	Mustard	102	99	73	25
Barley	Mustard	116	38	67	24
Barley	Mustard	105	39	70	24
Peas	Lettuce	40	172	35	*—35
Peas	Lettuce	58	169	38	—35
Oats	Red clover	104	175	40	—28
Oats	Red clover	122	143	43	—28
Oats	Maize	107	25	68	38
Barley	Maize	94	50	70	37
Barley	Maize	83	34	70	37

* The minus sign indicates that the secondary crop was planted before the primary crop.

In the field soil a major proportion of the tests resulted in a larger yield of the primary crop in the mixtures than when grown alone. As in the previous tests, a particularly heavy yield of a secondary crop was accompanied by a relatively lighter yield of the corresponding primary crop. This is very noticeable in the combinations of barley and buckwheat, oats and buckwheat, and oats and mustard. It is not possible to trace any relation between the influence of the secondary crop and the length of the growing period or the length of time between planting, as the duplicates do not vary much in these respects.

Certain plants that were used as secondary crops were particularly successful in promoting a good growth of the primary crops. These were mustard, buckwheat, maize, and red clover. In the experiments

in nitrate formation, maize and legumes were found to have a favorable influence on nitrate formation. The other two crops did not enter into these experiments.

The much more pronounced influence of the secondary crops on the growth of the primary crops in the field soil than in the nutrient solution in crushed quartz leaves some question as to whether the influence of the secondary crops on nitrate formation was a factor in the growth of the primary crops. The result of the experiments with nutrient solution opens the question as to whether there is any other way in which such an influence could be exerted, if indeed the secondary crop really does affect favorably the growth of the primary crop.

It is true that there are certain combinations of plants in which the primary crop made a better growth than it did in other combinations; but in most such cases the primary crop gave a larger yield in the combination than it did alone, thus indicating a favorable influence on the part of the secondary crop and not merely an innocuous one.

From other experiments results have been obtained that indicate a stimulating influence of certain kinds of plants on the growth of other kinds. Dandeno (1909) grew oats, barley, buckwheat, wheat, and flax in soil contained in greenhouse pots, both with and without underground shoots of Canada thistle, and repeated the experiment with a young elm tree. All the crops except buckwheat grew better with the roots of Canada thistle than alone. All grew less with the elm tree. The stimulating effect of the thistle was most pronounced twenty-two days after planting. Dandeno suggested as a cause the excretion of substances that might stimulate the growth of the other plant or release plant food not otherwise available, or, on the other hand, might injure the other plant or tie up soluble nutrient material.

It is reported by the Norsk Landmandsblad (1903) that in Jutland spruce trees make a good growth on waste areas where mountain pines grow, when their roots are in contact, but otherwise not. If the pine is cut down while the spruce is still young the latter will die or will make a sickly growth; if, on the other hand, it is not cut until after several years, the spruce not only will survive but appears to grow faster than would have been the case if the pine had been left standing. The Norwegian experimenters account for this by supposing that pines utilize atmospheric nitrogen and furnish spruces with a supply of nitrogen.

Through what process the stimulation that one plant often seems to exert on another is accomplished, still remains to be ascertained. This apparently resembles, in some ways, the stimulus that certain plants exert on nitrate formation. Thus the stimulus is exerted more strongly during the earlier part than during the later part of the life of the plant. This is indicated by the field experiments already described, in which nearly all the primary crops harvested at bloom gave a larger yield in combination than alone, while similar mixtures that were allowed to mature gave opposite results. As a considerable part of the nutrients absorbed by plants had been taken up when the time of blossoming came, the competition of the secondary crop during the later growth could not have been very severe. It was also noticed that in quartz cultures the secondary crop remained almost stationary during the later growth of the primary crop and made an excellent growth after the latter had ceased growth entirely. Like the effect of the plant on nitrate formation, there appears to be a depressing effect during the later stages of growth. Another point of resemblance is that the influence of certain kinds of plants is more marked than that of other kinds, and in this respect maize and red clover were found to be especially active in stimulating both processes.

The natural growth of plants in associations, in which one plant follows another in succession through a considerable part of the season, may be to some extent a utilization of this apparent property of the plant to stimulate the growth of other plants.

Summary

The nitrate content of soil under timothy, maize, potatoes, oats, millet, and soy beans was different for each crop when on the same soil. There was characteristic relationship between the crop and the nitrate content of the soil at different stages of growth. During the most active growing period of the maize crop, nitrates were frequently higher under maize than in cultivated soil bearing no crop. Under a mixture of maize and millet, nitrates at this period were higher than under millet alone, although the crop yields were about the same on both plats.

These phenomena may be accounted for on the assumption that nitrate formation is stimulated by some processes connected with the active growth and absorbing functions of some higher plants, particularly of maize, although there are indications that the maize plant obtains a

large part of its nitrogen in some form other than as nitrates; the combination of these conditions may account for the very high nitrate content of the soil under maize.

Under both maize and oats the nitrate content was higher during the period when the crop was making its greatest draft on the soil nitrogen than in the later stages of growth, in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing. Nitrates under these crops and under millet failed to increase late in the season, when nitrogen absorption had practically ceased, although uncropped soil showed a very large increase in nitrates at that time.

This, in conjunction with facts before mentioned, indicates a further influence of the crop on the process of nitrate formation, and may be accounted for on the supposition that during their later period of growth the plants exert in some manner a depressing influence on nitrate formation.

Aside from the influence of cultivation, the source of the great differences in the nitrates under the crops mentioned may be sought in the inherent differences between plants of different species in their stimulating or inhibiting influence on the production of nitrates, as well as in their relative rates, amounts, and forms of nitrogen absorption.

Changes in the moisture content or in the temperature of the soil after early summer had no important effect on the nitrate content of the soil under plants. On the uncropped soil an increase in moisture content was sometimes accompanied by an increase in nitrates and sometimes by a decrease.

Determinations of the rate of nitrification of soil from plats planted to alfalfa and timothy, respectively, showed the alfalfa soil to nitrify more rapidly than the timothy soil, both in the soil on which the crops had been grown continuously and in that from which they had been removed and on which the soil had been kept bare for two seasons. The formation of nitrates was in the same order when the soils were incubated with dried blood. It seems probable that the character of the organic matter left in the soil by the plants determines to some extent the rate of nitrate formation in this soil.

Plats of land planted to certain crops in 1910 were kept bare of vegetation during the early part of the growing season of 1911. Determinations of nitrates in the soil of these plats showed a distinct and characteristic

relation of the several plants to the nitrate content of the soil in the year following that in which the plants were grown.

Maize was the only crop following which the nitrates in the previously planted soil were higher than in the unplanted soil. Potato soil was the next highest in nitrates, and oat soil contained least nitrates.

Millet planted on these plats on July 1 was markedly influenced by the previous crops, but the luxuriance of growth was inversely proportional to the nitrate content of the plats.

In this case the beneficial influence of a crop on a succeeding crop was not to be attributed to the favorable influence exerted on nitrification, but this would doubtless differ with different soils; and if this effect of certain plants on nitrate formation in the following year should be of general application, the influence of a crop on nitrification may be an important factor in crop rotation.

Freezing and thawing produced a condition of soil favorable to nitrate formation. The well-known action of frost in producing a granular condition in a clay soil may have operated to some extent in accomplishing this. To what extent the greater activity of the nitrate-producing bacteria is due to aeration and how much it is due to the direct effect of cold in readjusting the equilibrium of the bacterial flora, it is impossible to say. The obvious effect is to overcome the depressing influence of the crop previously grown and to permit the resumption of nitrate formation.

Timothy maintained a lower nitrate content in the soil than did any other crop. Mixed grasses — *Phleum pratense*, *Agrostis alba*, *Poa pratensis* — gave much less nitrogen in the crop and the drainage water combined than was contained in the drainage water from unplanted soil. These facts indicate a strongly repressive influence of these plants on nitrate formation, and suggest a possible cause for the injurious effect of grass sod in orchards on soil in which the supply of available nitrogen is deficient.

Plants of two different kinds were grown, in combination and separately, in soil and in ground quartz containing nutrient solutions. In a considerable number of cases in which the plants were harvested at the blooming period or before, one or both kinds made a larger growth in the combinations than in the pure cultures, although there were at least twice as many plants growing in the mixed as in the pure cultures. This increased growth of one plant in association with another was apparently

not due to any increased supply of nitrates, since the apparent stimulation of growth occurred with nutrient solution in which all the nitrogen was in the form of nitrates, as well as with the soil.

ACKNOWLEDGMENT

The writers wish to express their obligation to E. W. Leland, who has had charge of the field plats during nearly the entire time that these experiments have been in progress and whose careful execution of that part of the work has contributed much toward the accuracy of the investigation.

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CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
OF THE COLLEGE OF AGRICULTURE

THE ACTION OF CERTAIN NUTRIENT AND NON-NUTRIENT BASES ON PLANT GROWTH

I. The Antitoxic Action of Certain Nutrient and Non-Nutrient Bases With Respect to Plants

II. The Toxicity of Manganese and the Antidotal Relations Between This and Various Other Cations With Respect to Green Plants

III. Toxicity of Various Cations

BY M. M. McCOOL
OF THE DEPARTMENT OF PLANT PHYSIOLOGY

ITHACA, NEW YORK
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THE ACTION OF CERTAIN NUTRIENT AND NON-NUTRIENT BASES ON PLANT GROWTH

THE ACTION OF CERTAIN NUTRIENT AND NON-NUTRIENT BASES ON PLANT GROWTH — I

THE ANTITOXIC ACTION OF CERTAIN NUTRIENT AND NON-NUTRIENT BASES WITH RESPECT TO PLANTS *

M. M. McCool

(*Received for publication July 1, 1912*)

In determining whether any substance or ion may act injuriously on plant growth, it is customary to compare the rate or amount of growth in the presence of such a substance with that in its absence. The presence of any chemical agents aside from the substance tested is a complication to be avoided, or at least controlled, if possible, since there may be either a direct reaction between the different substances in the substratum or an indirect influence exerted through changes induced in the plant. In testing any injurious action — such as inhibition or retardation of growth — of the mineral nutrients used singly in solution, it is important in the first place to compare the growth-rate with that of plants in pure distilled water. The distilled-water comparison is not ideal, but it is necessary. Further comparisons may be made with plants grown in full nutrient solutions. In the hands of various investigators this type of controlled experiment has yielded results of much value, and such results may be made useful in studying the more complex conditions existing in the soil.

REVIEW OF GENERAL LITERATURE

While making a study of the proper composition of nutrient solutions, Von Raumer (1883)† reported the observation that a solution containing magnesium without calcium is highly injurious to plants. Loew (1892a) reported the first extensive study of the function of these two nutrients and of a relation between them with respect to plants. In this valuable paper, which has been overlooked by some of the later investigators, Loew emphasizes two most important points: (1) In a nutrient solution lacking calcium the organism *Spirogyra* is rapidly injured, the injury being more rapid than when any other nutrient is omitted. (2) Although magnesium

* Laboratory of Plant Physiology, Cornell University, Contribution No. 9.
†Dates in parenthesis refer to bibliography.

is an essential mineral nutrient it is extremely injurious when there is no calcium in the culture solution, the presence of calcium in sufficient amount entirely preventing the toxic action of magnesium.

Loew regarded the toxic action as due to the displacement of calcium by magnesium in certain parts of the protoplast, with a consequent loss of function. Moreover, if sufficient quantities of calcium salts are placed at the disposition of the plant thus affected, then, in accordance with the law of mass action, the magnesium is again replaced by calcium and the normal equilibrium is restored. There is here a clear enunciation of the physiological balancing of magnesium by calcium. Loew appears to have been unaware of the earlier work on antagonistic action, in which certain physiological processes of animals or their effects on animal life were under investigation. However, since Loew studied plants, and since he developed one of the most important of the antagonistic relations — that between calcium and magnesium — his work may be made the starting point in this study.

Extensive data have been presented since 1899 concerning the antagonistic action of different bases with respect to both animals and plants. The work of Loew, Kearney, Loeb, Harter, Osterhout, and others has developed many facts respecting this phenomenon in general. It has been satisfactorily demonstrated that a solution of any one nutrient mineral base at some concentration below the limits of osmotic influence is commonly poisonous. (Some plants are apparently uninjured by calcium chlorid at concentrations approaching the point of plasmolysis.) Furthermore, this poisonous action, or toxicity, can be more or less completely counteracted, sometimes by one base but especially by such a combination of salts as enters into a balanced nutrient solution.

It will be the purpose of a later paper to summarize the data on the relative toxicity of the different bases, and to present some additional facts. The present discussion is confined to the question of the extent and significance of antitoxic action between certain bases. Further studies on this subject with some of the more toxic metals will also be reported later.

The work of Loew (1892 a), above referred to, established in an incontrovertible manner the antagonistic action of calcium and magnesium, but from this there are afforded no special indications that further antidotal relations may exist between other mineral bases. Indeed, Loew subse-

quently declared that between other pairs of mineral nutrients no relations of the same class occur.

In studying the effects on plants of certain salts of alkalin soils, Kearney and Cameron (1902) greatly extended the knowledge of toxic and antagonistic effects. Some of their conclusions are the following:

"Calcium chloride in pure solution is ten times less injurious than sodium chloride, and two hundred times less injurious than magnesium sulphate, if chemically equivalent solutions are considered.

"Addition of sodium ions to a solution containing magnesium ions in most instances markedly weakens the toxic action of the latter.

"Addition of calcium ions to solutions containing either sodium or magnesium ions nearly always counteracts to an extraordinary degree the injurious effect of the sodium or magnesium ions, this beneficial influence being usually much more marked when calcium is furnished as the sulphate than when the chloride is added.

"The effect of one kind of ion in counteracting the physiological action of another kind can not be entirely explained by a study of the chemistry of the solution itself, but must in part be referred to complicated changes in the protoplasm of the organisms. The theory that ions furnished by the dissociation of electrolytes form intimate combinations with the proteids of protoplasm, and that their mutually antagonistic effect expresses itself in a replacement of one kind of ion by another as a result of change in the composition of the surrounding solution, would appear to afford the key to this problem."

The results from one of the more general studies undertaken by Osterhout (1906) may be noted in this connection. These conclusions are important, although at the time Osterhout was apparently unaware of the earlier work on plants. He placed several forms of marine algæ in pure and mixed salt solutions and determined the duration of life in days. The following conclusions are drawn:

"1. Each of the salts of the sea water is poisonous where it alone is present in solution.

"2. In a mixture of these salts (in the proper proportions) the toxic effects are mutually counteracted. The mixture so formed is a physiologically balanced solution.

"3. Such physiologically balanced solutions have the same fundamental importance for plants as for animals."

In studying the toxicity of sodium and magnesium salts, Kearney and Harter (1907) placed seedlings in salt solutions for twenty-four hours and then transferred them to pure water. The inability of the roots to elongate further was taken as an indication that the concentration used was fatal to the root tips. Kearney and Harter made studies of the lethal concentrations of pure solutions and of solutions with different amounts of calcium sulfate added, employing as indicators a number of species of plants. They found that the addition of calcium sulfate greatly diminishes the toxicity of the sodium and magnesium salts to all the plants tested.

Among the many experiments bearing on this problem reported by Loeb (1905 a) the following may be mentioned: The marine fish *Fundulus* soon dies when placed in a pure solution of sodium chlorid. This is true even though the solution may be no stronger than that which exists in sea water. The toxicity of the sodium chlorid is counteracted by the addition of chlorids of calcium or potassium. The calcium and potassium serve primarily to counteract toxicity, and in this instance are unimportant as nutrient elements; for when the fish is placed in distilled water it lives for a considerable period of time.

The brief indications given above may serve to show the direction and importance of the work thus far undertaken. On the whole, many facts have been presented concerning the antagonistic action of different bases with respect to both animals and plants. Nevertheless, the data for the seed plants are still insufficient, the evidences of slightly unbalanced conditions on the development of the plants as a whole having received much less attention. With respect to unbalanced conditions in the soil the problems become most complex, and solution studies should make possible a more nearly accurate approach to the agricultural application.

The more recent work of Osterhout (1908, 1909) with wheat seedlings placed in pure and mixed salt solutions is important, but much more data are required. His conclusions also are based on a comparison of root growth alone. Furthermore, it cannot be seen from his tables, in many cases, to what extent one base antidotes another base. For example, the root growth of wheat seedlings placed in solutions containing 100 cubic centimeters of .12 mol.* $NaCl$ + 100 cubic centimeters of .12 mol. NH_4Cl (the resulting concentrations of each salt being .06) is compared

* As here employed, "mol." denotes a gram-molecular solution, that is, one containing the number of grams corresponding to the molecular weight of the substance dissolved to make 1 liter of solution.

with the root growth of those placed in pure solutions of .12 mol. NaCl and .12 mol. NH_4Cl, respectively. The increase in growth of the roots in the mixed solutions over that in the pure cultures is attributed wholly to the antagonistic action of the bases sodium and ammonium, whereas it is certainly due in part merely to the reduction of the concentration of each salt from .12 to .06 mol.; yet antagonism is obvious.

In view of all the considerations stated, a reinvestigation of antitoxic action with reference to certain seed plants has seemed especially necessary; likewise, it is important to extend the work so as to include certain bases that have been less studied.

SCOPE OF THE INVESTIGATION

The writer has concluded experiments with various nutrient and non-nutrient mineral bases, using Canada field peas and wheat as indicators. He has made a comparative study of the growth of tops and roots in solutions of the different salts containing single bases, in concentrations varying from those that are non-toxic to those that practically prohibit growth, and in solutions containing two bases at various concentrations including those strengths that are toxic when employed alone. An effort was also made to determine the minimum of one base that would antidote a given toxic amount of another base, but much remains to be done in this direction.

The experiments reported in the present bulletin include studies of the bases Ca, K, Na, NH_3, Mg, Sr, and Ba. In studying the relations of calcium and strontium ions they were combined as $Ca(NO_3)_2 + Sr(NO_3)_2$ and $CaCl_2 + SrCl_2$. The experiments with calcium and magnesium consisted of $CaCl_2 + MgCl_2$ and $CaCl_2 + MgSO_4$. In all other cases the chlorids only were used. Data which are to be presented show that calcium antidotes each of the bases mentioned above, and that definite mutual antagonism exists in the following combinations:

Mg and Sr	Na and NH_3
Mg and Ba	Na and Sr
Na and K	K and Sr

K and Ba

Other cases in which mutual antagonism may possibly occur are discussed later.

METHOD

Analyzed salts of high quality were used in all experiments. The normal (equivalent) solution was made the basis of comparison. A normal solution of a monovalent salt contains one gram molecule in a liter of solution; while a normal solution of a bivalent salt contains one half gram molecule in a liter. In general, stock solutions of N/1 were made and the desired concentrations were subsequently prepared by dilution. In some of the experiments wheat seedlings were used, in others Canada field peas. The seeds were treated for fifteen minutes with a solution of formaldehyde containing one part of the toxic agent in six hundred parts of water. Following this treatment the seeds were left in running water for twenty-four hours and were then allowed to germinate between filter papers over sphagnum or peat moss saturated with water. In this way entirely satisfactory seedlings were obtained.

FIG. 1.— *Showing method of making cultures. The black paper shell has been removed in order to expose the roots*

The seedlings, after having been washed with distilled water, were transferred to the culture solutions when the radicles were about two inches in length. At this stage of development there was no lateral branching of the roots. Seedlings of as nearly uniform size as possible were chosen for the cultures.

All glassware used in the experiments was carefully washed with the chromic-acid cleaning mixture and then rinsed with tap water and distilled water. Ordinary glass tumblers were used as culture vessels. Preliminary experiments were made in order to determine whether or not there is any appreciable difference in the growth of plants in distilled water and

in various solutions when resistant glass beakers are substituted for ordinary glass tumblers as containers of the culture solutions. The results showed conclusively that the differences are not recognizable. The use of the tumblers as receptacles for the solutions is thus justified. In order to support the seedlings and to prevent evaporation the tumblers were covered with paraffined wrapping paper, made secure by means of rubber bands. Holes were made in the paper and the radicles were inserted through these into the solutions below. The tumblers were also slipped into black paper shells.

If the tops of the seedlings grew to a height of three inches they were supported by means of wires carrying rings which projected directly above the tumblers. These wires held the tops of the plants upright and thus afforded uniform conditions of light.

The duration of the experiments was twenty-one to thirty days. Frequent observations were made until the end of the period, when generally the final notes were taken. The original amount of the solution was maintained by the addition of distilled water. The writer has found this method satisfactory. In all cases the essential data are given in the tables or in the text in connection therewith.

RELATION BETWEEN CALCIUM AND MAGNESIUM

Review of important field work

The calcium-magnesium relation of soils has been shown to be a most important one in crop production. Previous to the formulation of the view that there is a definite lime-magnesia ratio for maximum plant growth, many contradictory reports existed respecting the benefits or injuries from the application of lime and magnesia to soils.

As early as 1814, Davy (1814) discussed the injury that magnesia sometimes produces on crops. He wrote, "On mixing some calcined magnesia with soil in which different seeds are sown, it is found that they either die or vegetate in a very imperfect manner." He also states "that lime from magnesia limestone may be applied in large quantities to plots, and where lands have been injured by the application of too large quantities of magnesia lime, peat will be a proper and efficient remedy."

The deleterious influence of a high magnesium lime was reported by the United States Commissioner of Agriculture in 1876. Parts of a field fer-

tilized in one case with material obtained from a place near Belvidere, New Jersey, and in another case with material obtained from Oxford, New Jersey, showed injurious effects in the former, and beneficial action in the latter, on the crop growth. The difference between the two reactions was so striking that it was considered of importance to investigate the cause. Samples of the two limestones were sent to the United States Department of Agriculture, where they were analyzed. The injurious limestones were found to contain thirty-eight to forty-two per cent of magnesium carbonate, while the beneficial limestones contained not quite one per cent of this substance.

Adolf Mayer (1886) mentions unproductiveness as characteristic of soils rich in magnesia. On the other hand, Heiden (1869) cites some instances in which magnesia, and even magnesium sulfate, were beneficial when used as fertilizers on soil.

There are conflicting reports regarding the value of kainit and carnallite as fertilizers under different conditions. Kainit is composed of K_2SO_4, $MgSO_4$, $MgCl_2$, and water of crystallization. Carnallite is a double chlorid of potassium and magnesium. The effects were frequently found to be injurious when the salts were applied in spring, while the application in autumn proved beneficial. Thus Fleischer (1886) observed that when kainit was applied in autumn the yield of a crop of potatoes was five per cent greater than when kainit was applied in spring. Liebenberg (1896) reported a decrease in the yield of meadows when kainit was applied in autumn. In the latter case the perennial roots of grasses came in direct contact with the fresh fertilizer; while in the previous cases winter rains washed out or modified the injurious magnesium salt before seeds were sown.

The detrimental action of these salts is due mainly to their high magnesia content — which will do little harm on soils rich in lime and poor in magnesia. The more magnesia there is present in a soil, in relation to lime — other conditions being constant — the more injurious a certain additional quantity of magnesium compounds will prove.

It is thus evident, from these general experiments, that there are contradictory reports on the results from the application of various amounts of lime and magnesia to the soil. If it be assumed, however, as is permissible from data subsequently mentioned, that there is a certain favorable ratio between lime and magnesia, and particularly an injurious action from an

excess of magnesium, then these reports are not often inconsistent, especially when cognizance is taken of the widely different ratios of lime and magnesia in different soils and of other complex relations.

The composition of soils can be determined by means of chemical analyses, but such analyses do not reveal the ratio in which the various mineral nutrients are available to the plant. The elucidation of fundamental principles from soil studies is very difficult because of the many complex and uncontrollable factors existing therein.

Loew (1901), in a review of the ratio between lime and magnesia in soils of different countries, states:

"It will be seen from this review,

"1. That the ratio of lime to magnesia ranges between wide limits.

"2. That in the majority of cases lime predominates over magnesia.

"3. That in all the instances of great fertility the soil never shows any marked excess of magnesia over lime, but, on the contrary, generally more lime than magnesia."

He writes also: "Lime and magnesia can exert their indispensable nutritive functions only in a certain dependence upon each other. Hence a certain ratio between these two nutrients will produce the most favorable results, while a great excess of the one in the finest portion of the soil will lead to starvation and of the other to poisonous phenomena." It is therefore clear that the determination and balancing of the available amounts of magnesia and lime in the soil is necessary for successful farming on apparently infertile soils.

It was in attempting to explain the relation of calcium to magnesium that Loew (1892a) postulated the existence, in plants requiring calcium, of a calcium-protein compound in which the base is not replaceable by magnesium without serious injury to the protoplasm.

According to Sirker (1908), "a topdressing with a small quantity of magnesium sulphate at the rate of 10 kilo per hectar had the favourable effect of increasing the harvest by 31 per cent on a plot too rich in lime relatively to magnesia."

Review of some culture experiments

Investigations with oats, wheat, cowpeas, and tobacco, in water, sand, and soil cultures, were made by May (1901). The following general conclusions were reached:

"Magnesia in a soil in great excess over lime in a finely divided or soluble condition is noxious to the growth of plants. With a great excess of lime over magnesia the physiological action of the plant is hindered and it exhibits phenomena of starvation. An excess of lime counteracts the poisonous effects of magnesia, while the more favorable proportion of the two bases obviates the poor nutrition of the plant.

"The best proportion of soluble lime to soluble magnesia for the germination and growth of plants is about molecular weight 5 to 4, or actual weight 7 to 4.

"In liming soils the amount of lime and magnesia should be first determined in both the soil and the material applied. In this way only can the process be intelligently carried out and the best ratio between the two bases for the promotion of the growth of crops be maintained."

Meyer (1901) grew oats, potatoes, horse beans, vetch, and a mixture of equal amounts of rye grasses and alfalfa in pots of a capacity of six kilos, which contained, on the one hand, sand and peat (2½ per cent) and, on the other hand, sand and loess loam (10 per cent).

In the case of the oats-and-grass mixture, an application of gypsum at the equivalent rate of more than one gram CaO per pot caused a decided reduction of yield. The injurious effect of the gypsum was overcome by applications of calcium carbonate or magnesium carbonate.

Large applications of magnesium carbonate depressed the yield of the grass mixture. It was observed also that even when an excess of lime had been applied magnesia caused an increased yield.

With pot experiments Aso (1903) found that the ratio of lime to magnesia for the mulberry tree is about two or three parts of lime to one part of magnesia. An excess of magnesia over lime retards growth. In some experiments with rice Aso (1904) used in pot cultures soil that was taken directly from a paddy field. To these cultures were added varying amounts of calcium carbonate and magnesite. From the results obtained with this crop Aso concludes that the ratio of lime to magnesia for maximum growth is about the same as that most favorable for other *Gramineæ*, which is between 1:1 and 2:1.

Kanomata (1908) found that "when the amount of lime is increased in undue proportion to the amount of magnesia present, the yield of oats is considerably depressed. In sand culture, there was a decrease by 39 per cent of the weight of shoots before flowering time, when the amount of

limestone and magnesite differed so much that the ratio $\frac{CaO}{MgO}$ was changed from 1/1 to 100/1." This last point, however, does not appear to the writer to be established through sufficient experiments.

Daikuhara (1905 a) observed that "the yield of naked barley was not essentially altered when the amounts of these bases [calcium and magnesium] were rendered equal by adding $CaCO_3$ or $MgCO_3$," when the difference did not exceed .5 per cent. On well-manured soils in which the ratio was .34:1 the harvest was doubled by producing a ratio of 1:1.

The data obtained by the same author (1905 b) from sand cultures show that "in the presence of lime as carbonate the necessary amount of magnesia when applied as crystallized sulphate for paddy rice in sand culture is so small that the best ratio CaO:MgO becomes 30:1, while in the form of natural carbonates the best ratio would be 1:1."

The results given by Nakamura (1905) with barley grown in pots of soil "show decidedly that the addition of a certain quantity of magnesia acts very beneficially upon the growth of the plant when the soil contains a large excess of lime over magnesia and furnish at the same time a further proof of the inference that 'a maximum yield depends — other things being equal — also upon a certain ratio of lime to magnesia which enters into the plant.'"

Wheeler and Hartwell (1903) found that in pot cultures $CaCl_2$ and NH_4Cl exert "a marked poisonous action upon certain plants, when applied to a soil which was already somewhat acid. Magnesium chlorid was not found to be poisonous under conditions where great injury from calcium chlorid and ammonium chlorid resulted.

"Calcium carbonate and caustic magnesia used singly, also a mixture of basic slag meal with the carbonates of potash and magnesia, were found to prevent or overcome the ill effect produced by applications of either calcium chlorid or ammonium chlorid."

Bernardini and Siniscalchi (1908) grew lupine in pot cultures and concluded that "the injurious action of an excess of lime and the poisonous action of an excess of magnesia in the soil is not due to the absolute quantity of calcium and magnesium ions absorbed by the plant, but to the ratio in which they are absorbed."

Konovalov's results (1907) with wheat, lupine, and oats grown in water and sand cultures do not confirm Loew's view that "there is a definite

lime-magnesia ratio for each plant." The growth of the plants is injuriously affected when magnesia is present and lime is absent in nutrient solution. According to Konovalov the yield is increased with the increase of the proportion of lime to magnesia.

Culture experiments with rye, corn, and kidney beans are reported by Bernardini and Corso (1908). The nutrient solution contained the ratios of lime to magnesia (magnesia as 1) 3, 2, 1, ½, and ⅓. Rye gave the best result in the solution in which the relation of lime to magnesia equalled 1, and better results with the higher proportions than with the lower; corn gave the best result with the proportion of lime to magnesia equal to 2, and better with the higher than the lower, showing that an excess of lime does less harm than an excess of magnesia. In the pot experiments a soil of known composition was used and the proportions between lime and magnesia were made the same as in the nutritive solution experiments, and the same results were obtained with rye and corn; with kidney beans the proportion of lime to magnesia equal to 3 gave the best result.

Konovalov (1909) studied the ratio of $\frac{CaO}{MgO}$ for barley, millet, oats, and maize. He states:

" In sand cultures with oats and millet the ratios of lime and magnesia varied as follows: $\frac{13.4}{1}, \frac{6.7}{1}, \frac{3.3}{1}, \frac{1.6}{1}, \frac{0.8}{1}, \frac{0.4}{1}, \frac{0}{1}$.

" The data clearly show that the more lime there is in the nutritive solution the quantity of magnesia remaining the same, until the ratio of lime to magnesia becomes 6.7:1 the greater the yield of both millet and oats. When this ratio is exceeded the yield of millet decreases somewhat and that of oats very considerably, there being a falling off in yield of both grain and straw and the mean weight of the grain."

In water cultures with maize and barley, "the maximum yield of organic matter was obtained in case of barley when the ratio of lime to magnesia was 3.3:1 and in case of maize when the ratio was .8:1. The same ratio gave the maximum yield of above ground material."

Novel experiments with wheat and oats were conducted by Hansteen (1909). He inserted one of the primary roots of the same seedling into each of two glass tubes placed side by side. The tubes contained separate solutions; for example, in tube 1 was placed N/50 $Ca(NO_3)_2$, while tube 2 contained N/50 $Ca(NO_3)_2$ + N/50 $MgSO_4$. In this manner Hansteen

was able to determine the influence of various solutions on different roots of the same plant. The results substantiate the view that $Ca(NO_3)_2$ mollifies the deleterious properties of $Mg(NO_3)_2$ and $MgSO_4$. Furthermore, in solutions that contain no calcium, only slight elongation of the roots of wheat and oats takes place.

From experiments with flax grown in pots of soil in which the ratios $\frac{CaO}{MgO}$ were 1:1 and 2:1, respectively, Namikawa (1906) concluded that the most advantageous ratio of $\frac{CaO}{MgO}$ for flax is 1:1. The yield is 21 per cent lower in soil cultures that have the proportions of lime to magnesia 2:1 and 3:1. Similar results were obtained with spinach grown in sand cultures.

Maki and Tanaka (1906) grew barley to maturity in loamy and sandy soil cultures. Sufficient slaked lime was added to make the ratio $\frac{CaO}{MgO}$ about 3:1. This relation caused a decrease in the yield, or the soil was overlimed. When a sufficient quantity of magnesium sulfate was applied to make the ratio 1:1 in the overlimed soil, the harvest was almost as great as in the untreated soil. In case of the sandy soil the crop was greater than the control cultures.

Yokoyama (1908) observed that when oats are grown in pots containing sandy soil poor in lime and magnesia the addition of lime is injurious, due to the unbalanced ratio of lime to magnesia. Furthermore, such soils should be treated with dolomitic limestone in order to correct such unbalanced conditions.

In sand cultures Aso (1909) ascertained that the lime factor for oats is 1, for adzuki beans (*Phaseolus mungo*) about 2, for rice 1, and for Italian millet between .5 and 1. His conclusions are:

"1. Certain favorable ratio of lime to magnesia for plant-growth exists even in sandculture.

"2. Absolute excess of lime or magnesia provided it be kept within certain limits, has no retarding effect on the development of the plants, the ratio between these bases being the chief factor for plant growth."

Gile (1913), as a result of his work, states: "The toxicity of an excess of lime or magnesia is not due simply to an unfavorable ratio between these two salts alone, but to an unfavorable proportion between the salt which is in excess and all the other salts present."

Experimental work

In the experiments from which the data presented in this section were taken, the sulfates and chlorid of magnesium were used but only the chlorid of calcium; that is, in one series $CaCl_2$ and $MgCl_2$ were employed, in another $CaCl_2$ and $MgSO_4$. The different salts of magnesium were used in order to determine whether or not the acid radical is of importance in these studies.

A study of Table 1 shows that the chlorids and sulfates of magnesium are extremely toxic to pea seedlings. On the other hand, calcium chlorid, even at relatively high concentrations, is not poisonous. The development of the plants in the combined solutions is much greater than in pure solutions of magnesium chlorid or sulfate. The growth of the plants in the combined cultures does not, however, differ greatly from that of the plants in the solution of the calcium salt alone; for example, in N/20 $CaCl_2$ the total weight of the plants is 7.40 grams, in N/500 $MgCl_2$ the weight is practically nil, and in N/20 $CaCl_2$+N/500 $MgCl_2$ the total weight is 9.95 grams.

TABLE 1. Experiment with Canada Field Pea. Duration, Twenty-four Days. Data for Ten Plants

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots* (centimeters)
N/20 $CaCl_2$+N/20 $MgCl_2$	5.70	4.00	9.70	12.0	12.5
N/20 $CaCl_2$+N/100 $MgCl_2$	6.65	4.25	10.90	14.5	15.0
N/20 $CaCl_2$+N/500 $MgCl_2$	6.10	3.85	9.95	13.0	14.0
N/100 $CaCl_2$+N/20 $MgCl_2$	5.85	3.00	8.85	12.0	11.0
N/1,000 $CaCl_2$+N/20 $MgCl_2$	1.70	1.40	3.10	4.5	5.0
N/1,000 $CaCl_2$+N/100 $MgCl_2$	8.60	4.20	12.80	17.0	10.0
N/1,000 $CaCl_2$+N/200 $MgCl_2$	6.60	3.00	9.60	14.0	10.0
N/20 $CaCl_2$	5.00	2.40	7.40	8.5	12.0
N/100 $CaCl_2$	5.70	2.75	8.45	11.5	8.5
N/300 $MgCl_2$	—†	—†	—†	—	—
N/500 $MgCl_2$	—†	—†	—†	2.0	—
Distilled water	1.85	1.75	3.60	6.0	6.5
N/20 $CaCl_2$+N/20 $MgSO_4$	6.24	4.30	10.54	11.5	12.0
N/20 $CaCl_2$+N/100 $MgSO_4$	7.14	5.12	12.26	15.0	14.0
N/20 $CaCl_2$+N/500 $MgSO_4$	7.00	4.12	11.12	13.0	13.5
N/20 $CaCl_2$	5.85	2.60	8.45	9.0	12.5
N/500 $MgSO_4$	—†	—†	—†	3.0	—
Distilled water	1.72	1.84	3.56	6.5	7.0

* The average length of roots was determined by measuring the main roots. The lateral roots were not measured, as the weight is indicative of their development. These statements apply to all subsequent tables.

† Weak growth, plants almost dead, not weighed.

The action of the calcium is a very clear case of antagonism. It entirely overcomes the toxicity of both chlorid and sulfate of magnesium. It appears that the magnesium antidotes the calcium to a slight extent. This apparent antagonism, however, may be merely a benefit arising from the addition of another essential element, or at least it may not be due wholly to the antitoxic action of the magnesium. It is difficult to interpret mutual antagonism from data that show great decrease of toxicity in one direction and only slight decrease in the other.

Five days after the seedlings had been placed in the solutions the toxicity of magnesium was apparent. The roots in the culture contain-

FIG. 2.—*Antidotal relations between calcium and magnesium; distilled water as the solvent*

1. N/20 $CaCl_2$
2. N/20 $CaCl_2$+N/100 $MgCl_2$
3. N/100 $CaCl_2$+N/100 $MgCl_2$
4. N/1000 $CaCl_2$+N/100 $MgCl_2$
5. N/100 $MgCl_2$

ing N/500 $MgCl_2$ were dead, no growth having taken place. Ten days later the antagonism of calcium was clearly shown by the increased growth of the seedlings in the combined solutions over those in the solutions of magnesium alone.

Loew (1899) has drawn attention to the relative abundance, usually, of magnesium in the seeds of plants as contrasted with the magnesium content in other plant structures. This excess in the seed may enable the seedling, for a time at least, to exhibit a maximum growth in a solution containing no magnesium. As a result of numerous nutrition experiments in this laboratory with the pea, it has been clearly demonstrated that the demand of this plant for magnesium, or the necessity of maintaining a certain pro-

portion of magnesium in cultures with calcium salts or with full nutrient solutions (lacking magnesium), is unimportant during the first two weeks of growth. These results are in agreement with those obtained by König and Haselhoff (1894). These investigators found that *Leguminosæ* endure the lack of potassium better than the lack of calcium.

Numerous data have been brought forward which seem to show that a more or less definite ratio of calcium to magnesium is beneficial for plants. Many of the reports in which these data are embodied have been summarized. A further study of the antidotal relations that exist between these bases in full nutrient solutions is interesting and important. Canada field pea seedlings were grown in nutrient solution cultures containing calcium and magnesium in various proportions. The nutrient solution that was used as the solvent for these bases in series 1 was made up as follows:

$Ca(NO_3)_2$	4.00 grams
KH_2PO_4	1.00 gram
KNO_3	1.00 gram
$MgSO_4$	1.00 gram
KCl	0.50 gram
$FeCl_3$	0.01 gram
Distilled water	3.00 liters

No considerable antagonistic action is evident from cultures made up as were those in this series, inasmuch as the quantities of calcium and magnesium employed are not to be considered toxic under the conditions. However, a slight increase of growth ensues when either calcium or magnesium is added to the nutrient solution, but in general this is not so extensive as in the cultures to which both are added. The data obtained from this set of experiments appear in Table 2.

In this table toxicity is not evident, although the addition of calcium chlorid alone or calcium and magnesium together causes increased growth over the control (full nutrient alone). It may be that the full nutrient solution (Pfeffer's) is not a properly balanced solution for Canada field pea.

The nutrient solution employed in the second series of experiments (Table 3) was one tenth as strong as that in the preceding cultures.

TABLE 2. SERIES 1. EXPERIMENT WITH CANADA FIELD PEA. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution (nutrient solution as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)	Color of tops	Remarks
N/25 $CaCl_2$ + N/50 $MgCl_2$....	12.85	9.00	21.85	20	14	Light at tips	Lateral roots good length
N/25 $CaCl_2$ + N/100 $MgCl_2$...	14.15	8.25	22.40	20	12	Light at tips	Lateral roots good length
N/25 $CaCl_2$ + N/200 $MgCl_2$...	14.30	8.85	23.15	19	12	Good	Lateral roots good length
N/100 $CaCl_2$ + N/100 $MgCl_2$...	10.25	6.50	16.75	14	12	Good	Lateral roots medium length
N/500 $CaCl_2$ + N/100 $MgCl_2$...	8.45	4.60	13.05	12	10	Good	Lateral roots fair
N/1,000 $CaCl_2$ + N/100 $MgCl_2$...	10.70	5.60	16.30	15	14	Good	Lateral roots short
N/50 $MgCl_2$.....	10.55	5.90	16.45	15	12	Good	Lateral roots short
N/100 $MgCl_2$....	9.65	5.50	15.15	14	11	Good	Lateral roots medium
N/200 $MgCl_2$....	10.40	5.70	16.10	11	9	Good	Lateral roots medium
N/25 $CaCl_2$......	11.85	6.65	18.50	20	14	Pale green	Lateral roots medium
N/100 $CaCl_2$.....	13.50	7.90	21.40	17	9	Light green	Lateral roots good
Nutrient solution.	10.40	5.20	15.60	13	10	Good	Lateral roots fair

Toxic strengths of magnesium were used in these experiments. It is to be noted that in this nutrient solution N/10 $MgCl_2$ prevents growth of roots, and solutions of N/50 are injurious. The leaves of the plants grown in solutions of N/10 $CaCl_2$ are pale green in color, and those in N/100 $CaCl_2$ are somewhat lighter than in the control cultures.

The toxicity of N/10 $MgCl_2$ (Table 3) is greatly reduced, although not entirely prevented, by the same concentration of calcium chlorid. It is also to be noted that the harmful action of either N/20 or N/50 $MgCl_2$ is completely counteracted by solutions of N/10 $CaCl_2$. No injury results from the magnesium in cultures composed of this nutrient solution + N/100 $CaCl_2$ + N/50 $MgCl_2$.

In this series of experiments the addition of magnesium to the solutions of calcium has not resulted in an appreciable increase in the growth of the plants. It is to be observed, however, that the chlorotic condition induced by the calcium is prevented by the magnesium. A summary of the data obtained appears in Table 3.

TABLE 3. SERIES 2. EXPERIMENT WITH CANADA FIELD PEA. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution (1/10 nutrient solution as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Color of tops	Remarks
N/10 $CaCl_2$+N/10 $MgCl_2$	5.12	2.65	7.77	Dark green	Lateral roots very short
N/10 $CaCl_2$+N/20 $MgCl_2$	6.15	3.75	9.90	Dark green	Lateral roots very short
N/10 $CaCl_2$+N/50 $MgCl_2$	5.77	4.37	10.14	Light green	Lateral roots very short
N/10 $CaCl_2$+ N/100 $MgCl_2$	4.55	3.47	8.02	Light green	Lateral roots good development
N/100 $CaCl_2$+ N/50 $MgCl_2$	6.57	4.27	10.84	Green	Lateral roots good development
N/10 $CaCl_2$	5.00	4.10	9.10	Pale green	Lateral roots good development
N/100 $CaCl_2$	6.80	4.25	11.05	Light green	Lateral roots good development
N/10 $MgCl_2$	Weight not taken	No growth	——	——	Practically dead
N/50 $MgCl_2$	4.86	1.75	6.61	Dark green	Lateral roots short, dead
N/100 $MgCl_2$	6.00	3.75	9.75	Dark green	Lateral roots poor growth
1/10 nutrient solution	5.85	3.55	9.40	Green	Lateral roots good

RELATIONS BETWEEN OTHER BASES

Potassium and magnesium, sodium and magnesium

When wheat seedlings are placed in solutions of potassium and magnesium or sodium and magnesium chlorids (distilled water being the solvent), mutual antagonism is evident. In Table 4 it may be noted that N/1000 KCl can antidote the toxicity of N/500 $MgCl_2$ as completely as can N/50 KCl; while N/500 $MgCl_2$ seems to be the best concentration for antidoting N/50 KCl. The toxic action is manifest, particularly in the development of roots.

TABLE 4. EXPERIMENT WITH WHEAT. DURATION, THIRTY DAYS. DATA FOR EIGHT PLANTS

Composition of solution	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 KCl	0.65	5.5	1.0
N/50 KCl+N/100 $MgCl_2$	0.52	4.0	5.0
N/50 KCl+N/500 $MgCl_2$	1.00	7.0	6.0
N/50 KCl+N/1,000 $MgCl_2$	0.70	6.0	4.0
N/1,000 KCl+N/500 $MgCl_2$	1.00	7.5	5.0
N/500 $MgCl_2$	Dead	4.0	Slight
Distilled water	0.56	4.0	4.0

In Table 5 a striking case of mutual antagonism is shown between NaCl and $MgCl_2$. It is remarkable that two salts when combined will permit considerable growth, when if either one is present alone it will cause death of the plant.

TABLE 5. EXPERIMENTS WITH WHEAT. DURATION, THIRTY DAYS. DATA FOR EIGHT PLANTS

Composition of solution	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 NaCl	——*	2.0	0
N/50 NaCl+N/100 $MgCl_2$	0.400	4.0	1.0
N/50 NaCl+N/500 $MgCl_2$	0.800	5.5	4.0
N/50 NaCl+N/1,000 $MgCl_2$	0.650	5.5	2.0
N/500 NaCl+N/500 $MgCl_2$	——*	1.0	1.0
N/500 $MgCl_2$	——*	4.0	Very slight
N/50 NaCl+N/100 $MgCl_2$	0.900	8.0	8.0
N/50 NaCl+N/500 $MgCl_2$	0.975	9.0	13.0
N/50 NaCl+N/1,000 $MgCl_2$	1.125	9.0	12.0
N/100 NaCl+N/500 $MgCl_2$	1.150	11.0	10.0
N/500 NaCl+N/500 $MgCl_2$	0.840	9.0	6.0
N/1,000 NaCl+N/500 $MgCl_2$	0.810	8.0	5.0
N/500 $MgCl_2$	——*	6.0	0
N/1,000 $MgCl_2$	——*	8.0	Slight
N/50 NaCl	——*	1.0	0
N/100 NaCl	0.900	8.0	5.0
Distilled water	0.570	8.0	7.0

*Slight. Determination not made.

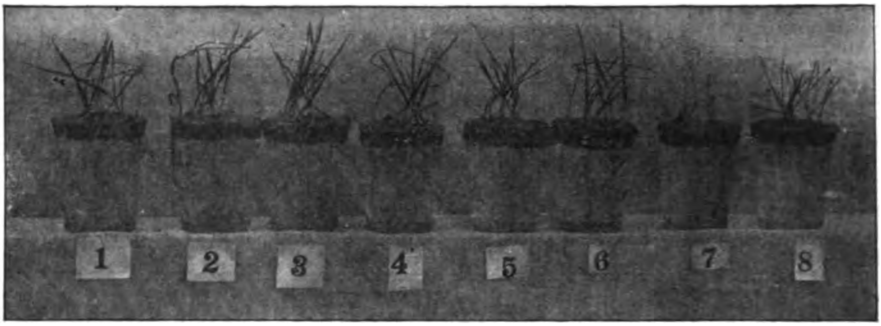

Fig. 3.— *Antidotal relations between sodium and magnesium; distilled water as the solvent*

1. N/50 NaCl + N/100 $MgCl_2$
2. N/50 NaCl + N/500 $MgCl_2$
3. N/50 NaCl + N/1000 $MgCl_2$
4. N/1000 NaCl + N/500 $MgCl_2$
5. N/50 NaCl
6. N/1000 NaCl
7. N/500 $MgCl_2$
8. Distilled water

Calcium and potassium

It has been shown by various investigators that salts of potassium are commonly much less toxic than those of magnesium. Nevertheless, a relatively weak concentration of KCl, N/50, will completely inhibit the growth of roots of the field pea; and it is only when the concentration is reduced to about N/500 that root growth is approximately equal to that when the plant is in distilled water. It has already been shown that calcium salts, at concentrations approaching the threshold of plasmolysis, may show little or no inhibition as compared with distilled water. When the salts of the two bases calcium and potassium are combined in certain proportions the toxicity of the potassium is entirely overcome, and the growth of the Canada field pea seedlings is considerably greater than in the corresponding concentrations of the calcium salt employed alone. This increase is of course partly due to the presence of another essential element. In general, the writer's results confirm and extend those of Kearney, Osterhout, Hansteen, and others, indicating that there is sufficient evidence to interpret the relation between these bases as one of mutual antagonism. Osterhout (1909), experimenting with wheat, has shown this relation as affecting root growth, and the following table includes some of the more significant of his results:

TABLE 6. WHEAT (GROWTH DURING THIRTY DAYS). QUANTITIES REPRESENT CUBIC CENTIMETERS OF .12 M SOLUTIONS

Culture solution	Aggregate length of roots per plant (millimeters)
$CaCl_2$	85
100 $CaCl_2$, 10 KCl	105
10 $CaCl_2$, 100 KCl	492
KCl	66

In the writer's experiments Canada field peas and wheat have both been employed, and in each case the presence of calcium protects the plant from the injurious action of potassium. As measured by the effect on the total green weight, the writer's results show a protective action which is not so marked as that which appears from the data of Osterhout, in which root length alone has been considered.

TABLE 7. EXPERIMENT WITH CANADA FIELD PEA. DURATION, TWENTY-FOUR DAYS

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)	Remarks
N/20 $CaCl_2$ + N/20 KCl	6.46	3.60	10.06	14.0	14.5	Tops dark green
N/20 $CaCl_2$ + N/50 KCl	6.60	3.85	10.45	15.0	15.0	Tops dark green
N/20 $CaCl_2$+N/500 KCl	6.35	3.95	10.30	14.0	15.0	Tops dark green
N/500 $CaCl_2$+N/20 KCl	5.25	3.20	8.45	12.0	8.0	Tops light green
N/20 $CaCl_2$	5.00	2.90	7.90	8.8	12.0	Tops light green
N/20 KCl	0	0	0	0	0	No growth, dead
N/50 KCl	Inap.*	0	Inap.*	Slight	0	Slight growth, dead
N/500 KCl	1.90	2.00	3.90	6.0	6.0	Terminal leaves dead
Distilled water	1.70	1.70	3.40	6.0	6.0	Color poor

* Inappreciable.

From an examination of the preceding table it is clear that a toxic solution of KCl strong enough to kill, N/20, may be rendered harmless by an equal quantity of calcium; while if the solution contains N/500 $CaCl_2$ to N/20 KCl, the maximum effect of calcium addition is not felt. On the other hand, with the maximum strength of the calcium salt employed, dilution of the KCl to N/500 does not materially affect growth as compared with that in the strongest combined concentrations employed. Inasmuch as the solutions containing calcium alone yield more growth than does the distilled water culture, the increase in growth of the plants in the combined solution over that in the solution of calcium alone should not be attributed wholly to the protective action of potassium with respect to calcium.

TABLE 8. Experiment with Wheat. Duration, Thirty Days. Data for Ten Plants

Composition of solution	Total green weight of plants (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/100 $CaCl_2$+N/100 KCl	2.65	12.5	12.5
N/100 $CaCl_2$+N/200 KCl	2.49	12.5	15.2
N/100 $CaCl_2$+N/400 KCl	2.45	12.3	15.0
N/100 $CaCl_2$	2.80	27.5	17.5
N/100 KCl	1.65	7.0	9.5
N/200 KCl	2.20	7.5	11.5
Distilled water	1.71	17.5	10.0

From a consideration of Table 8 it is seen that a solution of N/100 KCl is toxic for wheat seedlings (and it should be noted that a concentration of N/50 KCl practically prohibits growth); and this effect is to a considerable extent prevented by the addition of an equal quantity of calcium. Nevertheless, in the combined solution there is not so great a growth of tops as in the calcium alone, nor is the growth of tops in the combined solution quite so great as that in distilled water. With respect to wheat the experiments are not sufficient to determine whether or not there is a protective action of potassium toward calcium, since a toxic solution of the calcium salt was not employed.

Calcium and sodium

The relation between calcium and sodium has been considerably studied. Kearney and Cameron (1902), employing alfalfa and lupine, found that the greatest endurable concentration of sodium chlorid is .02 mol., while in the presence of calcium chlorid the amount of the sodium may be raised to .2 mol.

Attention has already been called to Loeb's (1905 a) experiments with the fish *Fundulus*. This animal cannot live in pure solutions of sodium chlorid isotonic with sea water. It can live for a long time in distilled water or in a mixture of NaCl, KCl, and $CaCl_2$ in the same proportions in which these salts are present in sea water. This is taken to show that the Ca and K ions are required only to overcome the poisonous effects of the sodium ion.

From experiments with wheat seedlings, Osterhout (1908) concludes that mutual antagonism exists between calcium and sodium. This is based on data of which the following form a part:

TABLE 9. WHEAT (GROWTH DURING THIRTY DAYS). QUANTITIES GIVEN ARE CUBIC CENTIMETERS OF .12 M SOLUTIONS

Culture solution	Aggregate length of roots per plant (millimeters)
$CaCl_2$	85
100 $CaCl_2$, 100 NaCl	198
5 $CaCl_2$, 100 NaCl	440
1 $CaCl_2$, 100 NaCl	300
NaCl	55
Distilled water	725

Osterhout states also that this relation is further established as a result of experiments with algæ, liverworts, and *Equisetum*.

The results cited are unusual and inexplicable in view of the greater root growth in distilled water than in the solutions of the combined salts, which result the writer is wholly unable to duplicate. It is noteworthy

that the most favorable growth in the mixed solution occurs when the calcium-sodium ratio is 1:20. In any case the protective action of the calcium is apparent, and it is important that so small a quantity of this substance is here required.

Aside from the discrepancy just cited, the writer's results with field peas are fairly comparable with those already mentioned. The data are presented in detail in tables 10 and 11. The sodium salt is strongly deleterious. A much stronger solution of sodium chlorid is required to prevent top growth than to prevent further elongation of roots. When N/50 NaCl is employed, slight development of tops occurs but there is no root extension. When seedlings are placed in N/100 NaCl, the development of tops is appreciable and the elongation of roots is very slight.

In a mixed solution N/5000 $CaCl_2$ + N/50 NaCl, the injurious property of the sodium is entirely counteracted. Thus calcium is a powerful antidote for sodium that is present in an injurious concentration. The same beneficial relation exists when the calcium ion is present in much stronger concentration, for example, in N/50 NaCl + N/20 $CaCl_2$. The growth of the seedlings is greater than in the pure solutions of calcium. Moreover, the results do not indicate, in general, that the most favorable ratio will involve a relatively small proportion of calcium.

TABLE 10. Experiment with Canada Field Pea. Duration, Twenty-four Days. Data for Ten Plants

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 NaCl+N/20 $CaCl_2$	6.10	4.00	10.10	14.0	14.0
N/50 NaCl+N/500 $CaCl_2$	5.15	3.80	8.95	12.0	14.0
N/50 NaCl+N/1,000 $CaCl_2$	6.20	3.40	9.60	15.0	11.0
N/50 NaCl+N/2,000 $CaCl_2$	6.00	3.45	9.45	15.5	10.5
N/50 NaCl+N/5,000 $CaCl_2$	6.10	3.25	9.35	15.0	10.0
N/100 NaCl+N/1,000 $CaCl_2$	4.70	2.50	7.20	12.5	9.0
N/50 NaCl	Small	0	Small	3.0	0
N/100 NaCl	Small	Inap.*	Small	4.0	Slight
N/20 $CaCl_2$	5.00	2.90	7.90	9.0	12.0
Distilled water	1.82	1.75	3.57	6.0	7.0

*Inappreciable.

TABLE 11. EXPERIMENT WITH CANADA FIELD PEA. DURATION, TWENTY-FOUR DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/100 NaCl+N/1,000 $CaCl_2$...	5.25	3.90	9.15	18.0	12.0
N/100 NaCl+N/2,000 $CaCl_2$...	6.50	4.60	11.10	25.0	14.0
N/100 NaCl+N/4,000 $CaCl_2$...	4.80	3.70	8.50	17.0	11.0
N/100 NaCl..................	Small	Inap.*	Small	4.0	2.0
N/1,000 $CaCl_2$................	6.20	3.30	9.50	22.0	13.0
N/2,000 $CaCl_2$................	5.10	2.20	7.30	18.0	10.0
N/4,000 $CaCl_2$................	4.80	2.10	6.90	19.0	9.5
Distilled water................	2.20	1.80	4.00	7.0	4.0

*Inappreciable.

Calcium and ammonium

The salts of ammonium are extremely injurious to green plants at relatively dilute concentrations. When wheat seedlings are placed in very dilute solutions of ammonium chlorid the deleterious action is exhibited in a pronounced manner by the inhibition of root growth. Immediate injurious effects on the tops are manifest only when the concentration is considerably increased. (An explanation of this behavior is reserved.) In this connection it is of interest to note that the salts of ammonium are in general considered agents which penetrate the cell more rapidly than do other salts. Experiments conducted by the writer with peas and wheat show conclusively that the deleterious effect of ammonium is greatly reduced by the addition of calcium; yet the calcium relation is apparently not modified by ammonium.

Mazé (1900) states that ammonium salts are poisonous to corn when present in greater amounts than .5 part per 1000 in the following solution:

Distilled water........................	1,000 cubic centimeters
KH_2PO_4............................	1.0 gram
$CaCO_3$..............................	2.0 grams
$MgSO_4$..............................	0.2 gram
$FeSO_4$..............................	0.1 gram
$MnCl_2$..............................	0.1 gram
$ZnCl_2$..............................	Trace
$K_2Si_2O_5$............................	Trace

He found the toxicity manifested particularly in the root development. The roots were retarded in their growth, being short and stubby.

TABLE 12. Experiment with Canada Field Pea. Duration, Twenty-four Days. Data for Ten Plants

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/20 $CaCl_2$	5.00	2.90	7.90	8.8	12.0
N/20 $CaCl_2$+N/100 NH_4Cl	3.75	2.90	6.65	11.0	12.0
N/20 $CaCl_2$+N/500 NH_4Cl	4.25	2.85	7.10	11.2	12.0
N/20 $CaCl_2$+N/1,000 NH_4Cl	4.15	2.50	6.65	8.5	12.0
N/100 $CaCl_2$+N/500 NH_4Cl	5.72	3.59	9.31	11.5	10.5
N/1,000 $CaCl_2$+N/1,000 NH_4Cl	5.26	2.65	7.91	12.5	10.0
N/5,000 $CaCl_2$+N/1,000 NH_4Cl	3.55	2.45	6.00	8.0	6.0
N/30 NH_4Cl	Not taken	——	——	2.0	0
N/500 NH_4Cl	1.65	1.80	3.45	6.0	6.0
N/1,000 NH_4Cl	1.72	1.90	3.62	6.5	6.0
N/5,000 NH_4Cl	1.80	2.10	3.90	6.3	6.5
N/100 $CaCl_2$	5.70	3.20	8.90	10.0	13.0
Distilled water	1.85	1.76	3.61	6.0	7.0

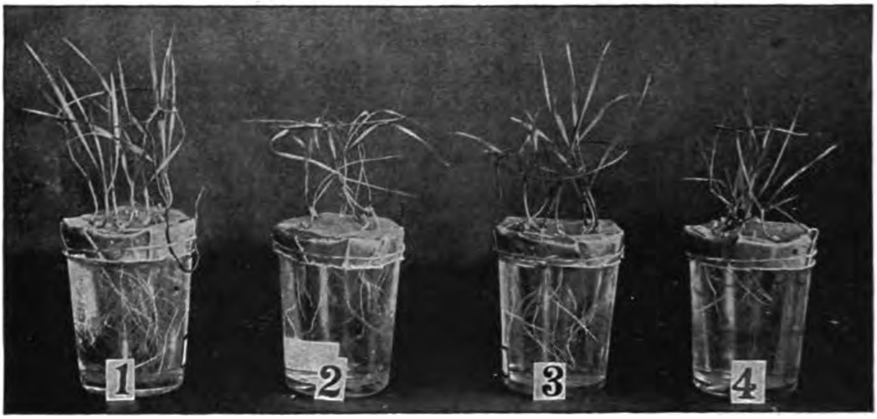

Fig. 4.— *Antidotal relations between calcium and ammonium; distilled water as the solvent*

1. N/20 $CaCl_2$
2. N/20 $CaCl_2$+N/500 NH_4Cl
3. N/50 $CaCl_2$+N/1000 NH_4Cl
4. N/1000 NH_4Cl

TABLE 13. EXPERIMENT WITH CANADA FIELD PEA. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
$N/100\ CaCl_2+N/1{,}000\ NH_4Cl$	2.00	9.0	8.0
$N/100\ CaCl_2+N/2{,}000\ NH_4Cl$	2.00	11.0	10.0
$N/100\ CaCl_2+N/3{,}000\ NH_4Cl$	2.54	10.0	10.0
$N/100\ CaCl_2+N/4{,}000\ NH_4Cl$	2.03	10.0	9.5
$N/30\ NH_4Cl$	0	2.0	0
$N/500\ NH_4Cl$	Weight not taken	2.0	Slight
$N/2{,}000\ NH_4Cl$	1.63	4.0	3.0
$N/3{,}000\ NH_4Cl$	1.67	4.0	3.0
$N/4{,}000\ NH_4Cl$	1.70	4.0	4.0
$N/100\ CaCl_2$	2.85	13.0	8.0
Distilled water	1.80	7.0	5.0

TABLE 14. EXPERIMENT WITH WHEAT. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution	Total green weight of plants (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
$N/100\ CaCl_2+N/1{,}000\ NH_4Cl$	0.95	12.5	12.5
$N/100\ CaCl_2+N/2{,}000\ NH_4Cl$	1.20	15.0	15.0
$N/100\ CaCl_2+N/3{,}000\ NH_4Cl$	1.40	15.5	12.5
$N/100\ CaCl_2+N/4{,}000\ NH_4Cl$	1.15	13.0	10.0
$N/2{,}000\ NH_4Cl$	1.16	9.0	Very slight
$N/3{,}000\ NH_4Cl$	1.10	10.0	Very slight
$N/4{,}000\ NH_4Cl$	1.16	11.0	8.0
$N/100\ CaCl_2$	2.88	17.5	27.5
Distilled water	1.71	10.5	17.5

The relations of calcium and ammonium in the complex nutrient solution have also been followed. The nutrient solution was of the same composition as that employed in the first series in which the calcium and magnesium relations were studied.

An examination of the data set forth in Table 15 shows that in this solution $N/25\ NH_4Cl$ is very injurious to the tops of seedlings, and

TABLE 15. EXPERIMENT WITH CANADA FIELD PEA. DURATION, TWENTY-FIVE DAYS. DATA FOR TEN PLANTS

Composition of solution (nutrient solution as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$+N/25 NH_4Cl	1.90	2.60	4.50	6.0	6.0
N/25 $CaCl_2$+N/25 NH_4Cl	5.50	4.52	10.02	11.0	12.0
N/50 $CaCl_2$+N/25 NH_4Cl	4.29	3.90	8.19	10.0	12.0
N/100 $CaCl_2$+N/25 NH_4Cl	4.91	4.95	9.86	9.0	11.0
N/500 $CaCl_2$+N/25 NH_4Cl	3.10	4.15	7.25	7.0	12.0
N/25 $CaCl_2$+N/500 NH_4Cl	11.95	7.80	19.75	18.0	13.0
N/25 $CaCl_2$+N/100 NH_4Cl	11.08	5.80	16.88	17.0	13.0
N/10 $CaCl_2$+N/50 NH_4Cl	6.81	4.31	11.12	11.0	8.0
N/50 $CaCl_2$+N/50 NH_4Cl	11.11	6.20	17.31	15.0	14.0
N/100 $CaCl_2$+N/50 NH_4Cl	10.35	5.70	16.05	14.0	12.0
N/500 $CaCl_2$+N/50 NH_4Cl	9.45	4.60	14.05	14.0	12.0
N/1,000 $CaCl_2$+N/50 NH_4Cl	8.45	4.38	12.83	12.0	12.0
N/25 NH_4Cl	3.50	3.80	7.30	7.0	12.0
N/50 NH_4Cl	9.75	4.85	14.60	11.0	11.0
N/100 NH_4Cl	8.80	4.40	13.20	12.0	12.5
N/500 NH_4Cl	9.60	6.56	16.16	17.0	11.0
Nutrient solution	10.40	5.20	15.60	13.0	10.0

FIG. 5.— *Antidotal relations between calcium and ammonium; nutrient solution as the solvent*

1. N/10 $CaCl_2$+N/25 NH_4Cl
2. N/25 $CaCl_2$+N/25 NH_4Cl
3. N/100 $CaCl_2$+N/25 NH_4Cl
4. N/500 $CaCl_2$+N/25 NH_4Cl
5. N/10 $CaCl_2$
6. N/25 $CaCl_2$
7. N/500 $CaCl_2$
8. N/25 NH_4Cl
9. Nutrient solution

to a somewhat less extent to the roots. Although slight growth results in the above cultures, death of tops soon occurs. N/50 NH_4Cl is only slightly toxic. The addition of either N/25, N/50, or N/100 $CaCl_2$ reduces the deleterious action of N/25 or N/50 NH_4Cl; whereas N/10 $CaCl_2$ increases the total injury, possibly due, however, to the general increase in concentration.

Sodium and ammonium

Mutual antagonism may be shown to exist between sodium and ammonium ions, wheat seedlings being employed as indicators. The writer's experiments show that death of the seedlings soon results when they are placed in a solution of N/50 NaCl. A solution of N/2000 NH_4Cl is poisonous to the seedlings. The toxicity of the ammonium ions of either N/100, N/500, or N/1000 NH_4Cl is greatly reduced by N/50 NaCl. Solutions of either N/500, N/1000, or N/2000 NaCl appreciably antidote N/1000 NH_4Cl. The toxicity of N/50 NaCl is clearly antidoted by NH_4Cl. The following data from the writer's experiments support these statements:

TABLE 16. EXPERIMENT WITH WHEAT. DURATION, TWENTY-ONE DAYS. DATA FOR EIGHT PLANTS

Composition of solution	Average length of tops (centimeters)	Average length of roots (centimeters)	Total green weight (grams)	Color of tops
N/50 NaCl+N/100 NH_4Cl	8	6	.50	Poor
N/50 NaCl+N/500 NH_4Cl	11	7	.95	Poor
N/50 NaCl+N/1,000 NH_4Cl	11	8	.90	Poor
N/500 NaCl+N/1,000 NH_4Cl	12	6	.75	Poor
N/1,000 NaCl+N/1,000 NH_4Cl	11	6	.72	Poor
N/2,000 NaCl+N/1,000 NH_4Cl	11	6	.69	Poor
N/50 NaCl	Slight growth	Slight growth	Weight not taken	Poor
N/500 NaCl	11	———	.86	Poor
N/2,000 NH_4Cl	4	4	.45	Poor
Distilled water	8	Slight growth	.95	Poor

Calcium and barium

Barium in soils.— Considerable interest was attached to the experiments with barium, since in recent times the occurrence and distribution of

barium in soils and in plants has received special attention. According to the results obtained by Failyer (1910), barium is a widely disseminated element. It is present in most soils of the United States, the larger quantities occurring in soils derived from masses carrying barite deposits. The original source in all cases seems to be the feldspars of the igneous rocks, the masses carrying barite being intermediate in formation. Barium may be expected to be present in small amounts in soil water. Crawford (1908) has noted its presence in various plants and has related its occurrence to the loco disease.

Toxicity of barium.—Although closely related to calcium the barium ion is extremely toxic in pure solution, and, since it is widely distributed in soils and is present in many kinds of plants, it is desirable to know definitely the effects on the barium ion of the calcium ion with respect to plant growth.

Relatively little work seems to have been recorded respecting the relations of barium. Through some experiments designed to determine the extent to which this element may replace calcium in the growth of plants, Suzuki (1910) found that, although barium is poisonous to plants at relatively dilute concentrations, this poisonous action can be lessened considerably by the presence of calcium salts.

The data obtained by the writer as a result of experiments with Canada field peas show clearly that barium is extremely poisonous to plants and may be rendered innocuous by calcium. Moreover, when barium and calcium ions are present in proper concentrations, the growth of pea seedlings may be slightly more extensive than in solutions of calcium alone.

TABLE 17. Experiment with Canada Field Pea. Duration, Thirty Days. Data for Ten Plants

Composition of solution	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/100 $CaCl_2$+N/2,000 $BaCl_2$	2.30	8.00	9.0
N/100 $CaCl_2$+N/4,000 $BaCl_2$	2.51	10.50	9.5
N/100 $CaCl_2$+N/8,000 $BaCl_2$	2.40	9.50	8.5
N/100 $CaCl_2$+N/10,000 $BaCl_2$	2.50	7.50	9.5
N/1,000 $BaCl_2$	0	0.25	0
N/4,000 $BaCl_2$	Weight not taken	4.00	Slight
N/8,000 $BaCl_2$	2.40	6.00	8.0
N/100 $CaCl_2$	2.65	8.50	9.5
Distilled water	1.43	7.00	6.0

TABLE 18. EXPERIMENT WITH CANADA FIELD PEA. DURATION, TWENTY-FOUR DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/20 $CaCl_2$+N/250 $BaCl_2$	5.50	3.90	9.40	10.0	8
N/20 $CaCl_2$+N/500 $BaCl_2$	5.45	4.15	9.60	9.5	11
N/20 $CaCl_2$+N/1,000 $BaCl_2$	5.65	3.65	9.30	15.0	9
N/20 $CaCl_2$+N/5,000 $BaCl_2$	4.55	3.70	8.25	9.0	11
N/100 $CaCl_2$+N/10,000 $BaCl_2$	5.25	3.52	8.77	10.5	12
N/1,000 $BaCl_2$	Weight not taken	0	Small	1.0	0
N/5,000 $BaCl_2$	0.82	Weight not taken	——	3.0	Slight
N/10,000 $BaCl_2$	1.82	1.90	3.72	6.5	7
N/20 $CaCl_2$	5.00	2.90	7.90	9.0	12
N/100 $CaCl_2$	5.70	3.20	8.90	10.0	13
Distilled water	1.70	1.75	3.45	6.0	6
N/10 $CaCl_2$	4.00	4.60	8.60	7.0	12
N/10 $CaCl_2$+N/1,000 $BaCl_2$	4.30	5.56	9.86	10.0	12
N/10 $CaCl_2$+N/4,000 $BaCl_2$	4.76	6.50	11.26	9.0	14
Distilled water	1.65	1.82	3.47	5.0	6

Magnesium and barium

With Canada field peas it was found that magnesium and barium antidote each other. The action is not great, however. Furthermore, as exhibited by the data, this antitoxic action is more evident when growth of roots is considered alone than when growth of both roots and tops is considered.

In this series N/800 $MgCl_2$ is approximately the lethal concentration, and in a solution of N/4000 $BaCl_2$ the root growth is slightly less than in distilled water. When magnesium and barium are offered together as N/800 $MgCl_2$ and N/4000 $BaCl_2$, the development is much greater than in distilled water. When a stronger solution of barium is combined with magnesium the solution is toxic. On the other hand, when N/800 $MgCl_2$ and N/6000 $BaCl_2$ are mixed in solution, the poisonous action of the magnesium is not appreciably reduced.

TABLE 19. Experiment with Canada Field Pea. Duration, Thirty Days. Data for Ten Plants

Composition of solution	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/800 $MgCl_2$+N/2,000 $BaCl_2$	0	3.0	0
N/800 $MgCl_2$+N/4,000 $BaCl_2$	2.40	8.0	8.0
N/800 $MgCl_2$+N/6,000 $BaCl_2$	1.85	7.0	7.0
N/800 $MgCl_2$	1.35	6.0	3.5
N/2,000 $BaCl_2$	0	3.0	Slight
N/4,000 $BaCl_2$	1.22	6.0	3.0
Distilled water	1.42	7.0	6.0

Potassium and barium

In order to obtain more extensive data with respect to potassium and barium ions, cultures were made up in which these cations were present alone and other cultures in which they were together in solution. The solvent employed was N/1000 $CaCl_2$. It was previously determined that N/1000 $CaCl_2$ is wholly ineffective in preventing the toxicity of barium at concentrations here employed. Osterhout (1907), discussing results obtained from experiments with wheat, states: "If we place grains of wheat in NaCl (or KCl) .05 M very little growth occurs. The addition of a very small quantity of barium (100 c.c. NaCl+1 c.c. $BaCl_2$ .05 M or 100 c.c. KCl .05 M+1 c.c. $BaCl_2$ .05 M) at once produces a splendid growth."

Toxic strengths of potassium and lethal concentrations of barium were employed in the experiments. It was found that when these ions are present together in the weak solution of $CaCl_2$ mentioned, mutual antagonism results. It is to be noted that N/25 KCl is highly injurious to seedlings and N/500 $BaCl_2$ prevents growth. Appreciable top growth takes place and the toxicity toward the roots is reduced, in cultures composed of N/25 KCl+N/500 $BaCl_2$. Similar results are obtained when N/25 KCl is present in solution with either N/1000 or N/2000 $BaCl_2$. In no combination is the top development of the plants so extensive as in those grown in the control, N/1000 $CaCl_2$.

TABLE 20. EXPERIMENT WITH CANADA FIELD PEA. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution ($N/1000\ CaCl_2$ as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
$N/25\ KCl$	Too dry to weigh	3.75	——	3.0	5.0
$N/25\ KCl+N/500\ BaCl_2$	1.75	5.37	7.12	5.0	10.0
$N/25\ KCl+N/1,000\ BaCl_2$	3.15	5.77	8.92	6.0	12.0
$N/25\ KCl+N/2,000\ BaCl_2$	2.35	4.85	7.20	3.5	7.0
$N/100\ KCl+N/1,000\ BaCl_2$	2.55	2.68	5.23	6.0	10.0
$N/1,000\ KCl+N/1,000\ BaCl_2$	2.10	2.50	4.60	5.0	8.0
$N/500\ BaCl_2$	0	0	0	0	0
$N/1,000\ BaCl_2$	Weight not taken	Slight	Slight	3.0	Slight
$N/1,000\ CaCl_2$	5.20	3.46	8.66	8.0	10.0

Calcium, potassium, sodium, or magnesium, and strontium

Suzuki (1910), while endeavoring to determine whether or not strontium can replace calcium in plants, called attention to the toxicity of this element. Osterhout (1907) has indicated that strontium has a protective action with respect to magnesium. He says: "In a solution of .05 M $MgCl_2$ or $MgSO_4$ or $Mg(NO_3)_2$ grains of wheat make scarcely any growth. But if to a solution of 100 c.c. $MgCl_2$ .05 M we add 20 c.c. $SrCl_2$ a very fine growth is observed."

The writer finds from experiments with pea and wheat seedlings that calcium, potassium, sodium, and magnesium each reduces the deleterious action of strontium, and that when strontium is present in solution with either of these the growth is greater than in pure solutions of these substances, as shown in the following tables. It will be noted that the growth in solutions in which nitrates were employed greatly exceeds that when chlorids are used. In the different tables, therefore, the data are not comparable.

Calcium and strontium.— From tables 21 and 22 it is evident that calcium and strontium have a mutually protective action. Calcium is very effective in reducing the harmful properties of strontium. $N/100$ $Sr(NO_3)_2$ is strongly toxic to both tops and roots of seedlings, while $N/500$ $Sr(NO_3)_2$ is injurious to the roots. When solutions of $N/20$ $Ca(NO_3)_2$ and $N/100$ $Ca(NO_3)_2$, respectively, are mixed with the above

concentrations of strontium the toxicity is entirely overcome. It is to be noted further that the addition of N/100, N/250, N/500, or N/1000 $Sr(NO_3)_2$ to N/20 $Ca(NO_3)_2$ results in a greater production of both tops and roots than occurs in N/20 $Ca(NO_3)_2$ alone. The increase in growth cannot be attributed to the addition of the nitrate radical to the calcium solution, inasmuch as similar relations exist between the chlorids of these metals.

The more concentrated solutions of strontium cause an increase in diameter of the roots of pea seedlings. Slight elongation takes place and no lateral roots are formed. As indicated in Table 21, less concentrated solutions are required to injure the roots than to produce injury to the tops.

TABLE 21. EXPERIMENT WITH CANADA FIELD PEA. DURATION, TWENTY-FOUR DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/20 $Ca(NO_3)_2$+N/100 $Sr(NO_3)_2$..	7.80	4.40	12.20	23.0	13.0
N/20 $Ca(NO_3)_2$+N/250 $Sr(NO_3)_2$..	7.20	4.20	11.40	22.5	12.5
N/20 $Ca(NO_3)_2$+N/500 $Sr(NO_3)_2$..	7.25	4.27	11.52	23.5	14.0
N/20 $Ca(NO_3)_2$+N/1,000 $Sr(NO_3)_2$.	9.20	4.70	13.90	24.0	11.0
N/100 $Ca(NO_3)_2$+N/250 $Sr(NO_3)_2$.	7.85	3.70	11.55	19.0	9.0
N/100 $Ca(NO_3)_2$+N/500 $Sr(NO_3)_2$.	7.35	3.45	10.80	18.5	8.0
N/20 $Ca(NO_3)_2$..................	7.30	3.20	10.50	16.0	11.5
N/100 $Ca(NO_3)_2$.................	7.95	3.70	11.65	16.0	7.9
N/50 $Sr(NO_3)_2$..................	Slight	0	———	2.0	Slight
N/100 $Sr(NO_3)_2$.................	1.60	1.20	2.80	5.5	4.0
N/500 $Sr(NO_3)_2$.................	3.20	1.35	4.55	8.5	3.5
N/1,000 $Sr(NO_3)_2$...............	2.40	1.50	3.90	8.0	6.0
Distilled water..................	1.75	1.70	3.45	6.0	6.5

TABLE 22. EXPERIMENT WITH CANADA FIELD PEA. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$..................	4.10	4.60	8.70	7.0	12.0
N/10 $CaCl_2$+N/500 $SrCl_2$......	4.30	6.10	10.40	9.0	14.0
N/500 $SrCl_2$.................	1.45	1.24	2.69	6.0	5.5
Distilled water................	1.65	1.82	3.47	5.0	6.0

FIG. 6.— *Antidotal relations between calcium and strontium; distilled water as the solvent*

13. N/100 $Sr(NO_3)_2$
14. N/500 $Sr(NO_3)_2$
15. N/1000 $Sr(NO_3)_2$
16. N/5000 $Sr(NO_3)_2$
17. N/20 $CaCl_2$+N/100 $Sr(NO_3)_2$
18. N/20 $CaCl_2$+N/500 $Sr(NO_3)_2$
19. N/20 $CaCl_2$+N/1000 $Sr(NO_3)_2$
20. N/100 $CaCl_2$+N/250 $Sr(NO_3)_2$
21. N/100 $CaCl_2$+N/500 $Sr(NO_3)_2$
22. N/20 $CaCl_2$
23. N/100 $CaCl_2$
24. Distilled water

Potassium and strontium.—Both potassium and strontium are strongly toxic to the roots of wheat seedlings. It is to be noted in Table 23 that the root development is slight in solutions of either N/50 KCl or N/2000 $SrCl_2$. It is shown further that the top growth of the wheat in these solutions is greater than that in distilled water. The deleterious action is counteracted when these salts are mixed in distilled water. In a solution containing N/50 KCl+N/2000 $SrCl_2$ the development of both tops and roots of the seedlings is greater than those grown in individual solutions of these salts. When N/1000 KCl and N/1000 $SrCl_2$ are combined, the poisonous action of the strontium is but slightly reduced.

TABLE 23. EXPERIMENT WITH WHEAT. DURATION, TWENTY-FIVE DAYS. DATA FOR TEN PLANTS

Composition of solution	Total green weight of plants (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 KCl+N/100 $SrCl_2$	0.762	8.0	9.0
N/50 KCl+N/500 $SrCl_2$	1.250	10.0	9.0
N/50 KCl+N/2,000 $SrCl_2$	1.500	10.0	10.0
N/1,000 KCl+N/1,000 $SrCl_2$	1.000	8.0	2.0
N/2,000 $SrCl_2$	0.750	7.5	1.5
N/20 KCl	0	0	0
N/50 KCl	0.810	8.0	1.5
Distilled water	0.680	7.0	6.0

Sodium and strontium.—With these bases also, as with potassium and strontium, is shown a clear case of mutual antagonism. By combining a solution of sodium with one of strontium, each of which, when alone in solution, is detrimental to wheat plants, no detrimental action results. Sodium is not so effective as potassium in overcoming the harmful properties of strontium. For example, an N/500 NaCl solution does not reduce the toxicity of N/1000 $SrCl_2$ to any greater extent than does a solution of N/1000 KCl. A comparison of the data in Table 23 with those in Table 24 discloses the fact that the growth of wheat seedlings is less when placed in cultures containing sodium and strontium than when placed in solutions of similar composition of potassium and strontium.

TABLE 24. Experiment with Wheat. Duration, Twenty-five days. Data for Ten Plants

Composition of solution	Total green weight of plants (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 NaCl	0.51	4.0	0
N/50 NaCl+N/100 $SrCl_2$	0.71	6.0	5.0
N/50 NaCl+N/500 $SrCl_2$	1.05	8.5	9.0
N/50 NaCl+N/2,000 $SrCl_2$	1.10	9.0	8.0
N/500 NaCl+N/1,000 $SrCl_2$	1.10	7.0	2.0
N/2,000 $SrCl_2$	0.75	7.5	1.5
Distilled water	0.68	7.0	6.0

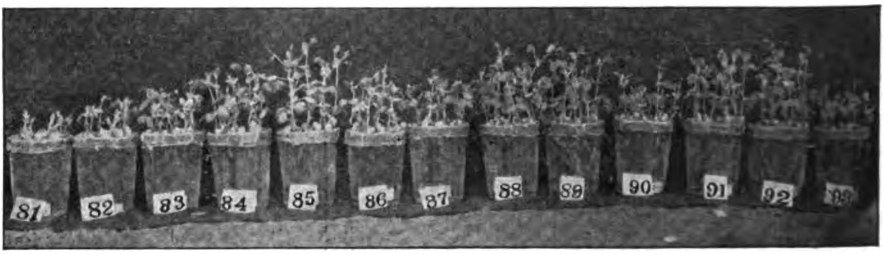

Fig. 7.—*Antidotal relations between sodium and strontium; distilled water as the solvent*

81. N/20 $NaNO_3$
82. N/50 $NaNO_3$
83. N/100 $NaNO_3$
84. N/50 $NaNO_3$+N/500 $Sr(NO_3)_2$
85. N/50 $NaNO_3$+N/1000 $Sr(NO_3)_2$
86. N/50 $NaNO_3$+N/3000 $Sr(NO_3)_2$
87. N/500 $NaNO_3$+N/500 $Sr(NO_3)_2$
88. N/500 $NaNO_3$+N/1000 $Sr(NO_3)_2$
89. N/500 $NaNO_3$+N/3000 $Sr(NO_3)_2$
90. N/100 $Sr(NO_3)_2$
91. N/500 $Sr(NO_3)_2$
92. N/5000 $Sr(NO_3)_2$
93. Distilled water

Magnesium and strontium.— It has been seen that magnesium and strontium are toxic at comparatively weak concentrations. However, when these bases are combined in the proper proportions and concentrations this toxicity is mutually counteracted.

Inasmuch as Canada field pea seedlings elongate but little in the absence of calcium, a trace of this compound — N/1000 $CaCl_2$ — was added to each of the cultures in the experiments noted below. With the increase in growth obtained by the addition of calcium the antidoting action of the bases magnesium and strontium is more obvious.

TABLE 25. EXPERIMENT WITH CANADA FIELD PEA. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution (N/1000 $CaCl_2$ as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/200 $MgCl_2$+N/100 $SrCl_2$....	1.35	3.05	4.40	5	9
N/200 $MgCl_2$+N/500 $SrCl_2$....	2.76	3.10	5.86	7	9
N/200 $MgCl_2$+N/1,000 $SrCl_2$...	3.75	3.70	7.45	7	10
N/500 $MgCl_2$+N/500 $SrCl_2$....	3.50	3.20	6.70	8	8
N/1,000 $MgCl_2$+N/500 $SrCl_2$...	3.20	3.06	6.26	8	9
N/100 $SrCl_2$..................	1.00	3.20	4.20	3	8
N/500 $SrCl_2$..................	3.55	2.10	5.65	7	9
N/200 $MgCl_2$..................	1.45	2.14	3.59	4	7
N/1,000 $CaCl_2$................	5.01	3.35	8.36	8	10

The writer's experiments demonstrate a definite antagonistic action between magnesium and strontium. The toxicity is not entirely overcome, since the growth in the mixed solutions is not so extensive as in the control, N/1000 $CaCl_2$. Mutual antagonism exists when these bases are present in diverse ratios; for example, it occurs in solutions made up as follows: N/200 $MgCl_2$+N/100 $SrCl_2$ and N/200 $MgCl_2$+N/1000 $SrCl_2$. The greater growth occurs in the latter solution.

Sodium and potassium

Osterhout (1909), in working with wheat, observed that mutual antagonism exists between sodium and potassium. The data presented below are taken from one of his tables:

TABLE 26. Wheat (Growth during Thirty Days). Quantities Given are Cubic Centimeters of .12 M Solutions

Culture solution	Aggregate length of roots per plant (millimeters)
NaCl	55
100 NaCl, 10 KCl	115
100 NaCl, 35 KCl	130
35 NaCl, 100 KCl	80
KCl	65
Distilled water	725

Hansteen (1909) found only slight antagonism between sodium and potassium in distilled water. Wheat was used as the indicator.

The harmful influences of potassium and sodium are reduced when these bases are combined even in widely different ratios. From the experiments with pea seedlings it is seen that a solution of N/500 NaCl very slightly reduces the toxicity of N/50 KCl. The minimum amount of potassium that may antidote a given amount of sodium was not determined, but relatively dilute solutions reduce the poisonous action of comparatively concentrated solutions of sodium. The solutions used and the data obtained are given in the following table:

TABLE 27. Experiment with Canada Field Pea. Duration, Twenty-four Days. Data for Ten Plants

Composition of solution	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 NaCl+N/50 KCl	2.56	6.00	4.00
N/50 NaCl+N/100 KCl	3.30	8.00	7.00
N/50 NaCl+N/500 KCl	4.40	11.00	11.00
N/100 NaCl+N/50 KCl	2.25	6.50	4.00
N/500 NaCl+N/50 KCl	1.60	5.00	Very slight
N/50 KCl	——	0.75	0
N/100 KCl	1.70	5.00	4.00
N/500 KCl	1.80	5.50	4.50
N/50 NaCl	0	Slight	0
N/100 NaCl	Slight	4.00	2.00
N/500 NaCl	2.60	7.00	7.00
Distilled water	1.74	6.00	6.50

FIG. 8.—*Antidotal relations between sodium and potassium; distilled water as the solvent*

47. N/50 KCl
48. N/100 KCl
49. N/500 KCl
50. N/50 NaCl
51. N/100 NaCl
52. Distilled water
53. N/50 NaCl + N/50 KCl
54. N/50 NaCl + N/100 KCl
55. N/50 NaCl + N/500 KCl
56. N/100 NaCl + N/50 KCl
57. N/500 NaCl + N/50 KCl

A comparison of the data in Table 27 with those in tables 7 and 10 reveals the fact that calcium is far more effective in overcoming the harmful action of either sodium or potassium than is any combination of the latter. Both the top and the root growth are greater when either of these bases is combined with calcium than when the two bases are combined together.

At the close of the experiment the color of the tops in all solutions was very poor. This was no doubt due to the absence of calcium from the cultures.

THE INFLUENCE OF AGE OF SEEDLINGS ON TOXIC AND ANTITOXIC RELATIONS

The influence of age of seedlings on the toxicity of barium, sodium, strontium, and ammonium, and the antidotal relations between calcium and each of these ions, have been studied. Pea seedlings were grown for ten days in a full nutrient solution. They were then removed, carefully rinsed with distilled water, and placed in pure solutions of $CaCl_2$ and in solutions of $CaCl_2$ mixed with each of the above salts. Twenty days later the experiments were discontinued. The data in the following paragraphs are obtained from seedlings thus treated.

Calcium and barium

Additional antidotal relations of calcium and barium with respect to pea seedlings are summarized in the following table:

TABLE 28. Experiment with Canada Field Pea. Duration, Thirty Days. Data for Ten Plants

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$+N/100 $BaCl_2$...	5.20	4.20	9.40	13.0	8.0
N/10 $CaCl_2$+N/500 $BaCl_2$...	5.80	4.70	10.50	11.0	9.0
N/10 $CaCl_2$+N/1,000 $BaCl_2$.	7.40	5.20	12.60	13.0	8.5
N/500 $BaCl_2$...............	Dead	Slight	——	Very slight growth	Very slight growth
N/1,000 $BaCl_2$.............	4.20	2.85	7.05	17.0	7.0
Distilled water.............	5.30	3.45	8.75	10.0	6.0

A comparison of the data presented in tables 17 and 28 reveals the fact that older seedlings are far more resistant to barium ions. It may be cited, for example, that N/4000 $BaCl_2$ prevents further elongation of the roots of young seedlings, whereas N/500 is required to kill older seedlings. The greater resistance may be due to mass relations; that is, the salts taken up from the nutrient solution may prevent the entrance of barium ions from the weaker solutions. Again, the more nearly complete migration of the storage products from the seed to the root may react in like manner. Furthermore, the permeability of the cell membrane may be altered and thus the entrance of the toxic ions may be retarded. The first postulation is unlikely, as the writer has found from several sets of experiments that seedlings which have been grown for ten days in distilled water are apparently no more susceptible to toxic ions than are those grown for the same length of time in full nutrient solution.

Stronger solutions of barium are required to exert toxic action toward older seedlings; but in this case also calcium is effective in preventing the

injurious action. When N/10 $CaCl_2$ is present in solution with either N/100, N/500, or N/1000 $BaCl_2$, no injury results.

Calcium and sodium

The results obtained from further studies of the relations between calcium and sodium are similar to those just discussed. Older seedlings are more tolerant of sodium ions than are younger ones. Seedlings taken from the germinating pan and placed directly in N/100 NaCl soon perish. On the other hand, those that are grown for ten days in a full nutrient solution withstand any solutions weaker than N/20. Calcium chlorid of N/10 concentration prevents injury from N/20 NaCl. The data obtained appear in Table 29:

TABLE 29. EXPERIMENT WITH PEA SEEDLINGS. DURATION, THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$ + N/20 NaCl	6.85	5.65	15.0	9.0
N/10 $CaCl_2$ + N/100 NaCl	7.14	6.37	13.0	8.0
N/10 $CaCl_2$ + N/500 NaCl	8.18	7.37	15.0	8.0
N/10 NaCl	No growth	Weight not taken	——	——
N/20 NaCl	Dead	Weight not taken	Slight growth	——
N/100 NaCl	5.00	4.00	9.5	7.5
N/500 NaCl	4.60	4.25	10.0	8.0
N/10 $CaCl_2$	7.90	6.00	17.0	7.0
Distilled water	5.30	3.45	10.0	6.0
Nutrient solution	12.40	8.25	15.0	10.0

Calcium and strontium

Older seedlings are also more resistant to strontium ions than are younger seedlings. Calcium is effective in preventing this deleterious action, since no injury results in solutions composed of N/100 $CaCl_2$+N/50 $SrCl_2$. The essential data are set forth in the following table:

TABLE 30. Experiment with Canada Field Pea. Duration, Thirty Days. Data for Ten Plants

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$ + N/50 $SrCl_2$	7.50	7.30	14.80	15	9
N/10 $CaCl_2$ + N/100 $SrCl_2$	9.00	5.90	14.90	15	8
N/10 $CaCl_2$ + N/500 $SrCl_2$	7.64	5.75	13.39	16	7
N/100 $CaCl_2$ + N/50 $SrCl_2$	5.36	4.45	9.81	12	8
N/50 $SrCl_2$	Dead, weight not given	4.45	——	6	11
N/100 $SrCl_2$	Dead, weight not given	5.60	——	7	11
N/500 $SrCl_2$	5.50	4.27	9.77	11	8
N/10 $CaCl_2$	9.75	6.00	15.75	17	7
Distilled water	5.40	3.55	8.95	10	6
Full nutrient solution	10.40	8.65	19.05	15	10

Calcium and ammonium

Seedlings that have been grown for ten days in full nutrient solutions are also more resistant to ammonium than are those taken from the germinating pan and placed directly in the solutions. N/100 NH_4Cl is the weakest solution that is toxic in the former case and N/3000 to N/4000 in the latter. The toxicity of either N/25 or N/100 NH_4Cl is reduced by the presence of N/10 $CaCl_2$. The results obtained appear in the following table:

TABLE 31. Experiment with Canada Field Pea. Duration, Thirty Days. Data for Ten Plants

Composition of solution	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$ + N/25 NH_4Cl	Weight not taken	13	Dead after ten days
N/10 $CaCl_2$ + N/100 NH_4Cl	12.21	18	8
N/10 $CaCl_2$ + N/500 NH_4Cl	16.35	22	7
N/10 $CaCl_2$	18.85	24	11
N/25 NH_4Cl	——	Dead	——
N/100 NH_4Cl	13.35	12	7
Distilled water	11.95	14	8

DISCUSSION

The reports of favorable results from the application of lime to various types of soil require only the briefest consideration here, since in this report only antagonistic phenomena are referred to. In soil studies the factors and relations are complex, and it is often difficult, if not impossible, to evaluate carefully the antagonistic features. Leaving out of consideration the effects of liming on acidity, its relation to nitrogen fixation and to toxic organic constituents of the soil, and the like, there remains the fact that the addition of lime compounds, both alone and in conjunction with other fertilizers, has resulted in marked increases in yield. The injurious action resulting when unbalanced conditions prevail, and the importance of calcium in correcting this action, make it probable that in many cases the beneficial effects obtained from calcium compounds are due to antagonistic relations. In any event the general trend of results indicates that where any single fertilizer has proved injurious it would be well to apply a calcium compound, at least in limited quantity.

It is not proposed to discuss in detail the views regarding the causes of antagonistic action, but some reference has already been made to the "calcium-protein" theory of Loew (1892 a). Mention should likewise be made of some subsequent papers. Loeb (1905 a) developed further the conception of ion protein compounds in explaining certain aspects of antagonistic action. With the development of colloidal chemistry and the discovery of antagonistic action with respect to the action of salts on proteins, new possibilities became apparent. By employing plasmolytic methods Osterhout (1911) finds that the mechanism of antagonistic action may depend largely on the mutual action of the antagonistic salts in preventing each other from entering, but there must also be taken into account their effect on the protoplasm. Later (1912) he confirms this statement. Loeb (1911) concludes that "the rôle of salts in the preservation of life consists in the 'tanning' effect which they have upon the surface films of the cells, whereby these films acquire those physical qualities of durability and comparative impermeability, without which the cell cannot exist." On the other hand, True and Bartlett (1912) submit evidence from electrolytic conductivity determinations indicating that it is not merely the endosmosis of solutes, but likewise the exosmosis of solutes, which is affected by concentration and relation of the salts. The writer

has made some experiments which show that the permeability of the cell is altered, the data of which are reserved for future consideration.

SUMMARY

The results of extensive studies of the toxic and the antidotal action of various ions have been presented. A general summary of these results appears below:

Pure solutions of N/500 $MgCl_2$ or $MgSO_4$ prevent further elongation of roots of seedlings. The toxicity of this cation is prevented by calcium in cultures composed of N/20 $CaCl_2$ with N/20 or any greater dilution of $MgCl_2$; and N/1000 $CaCl_2$ is effective with N/200 $MgCl_2$, but not with N/20 $MgCl_2$. N/50 $MgCl_2$ or higher concentrations are toxic in a dilute full nutrient solution. The further addition of $CaCl_2$ counteracts this injurious action.

Mutual antagonism exists for wheat seedlings when N/50 KCl is present in solution with N/100 to N/1000 $MgCl_2$. N/1000 KCl likewise counteracts the toxicity of N/500 $MgCl_2$.

The sodium and magnesium relations are similar to those of potassium and magnesium; however, sodium is not so effective as potassium in antidoting the magnesium ion.

No elongation of roots of pea seedlings takes place in N/20 KCl; but the presence of $CaCl_2$ at a concentration of N/20 to N/500 completely counteracts this deleterious action.

Very dilute solutions of calcium are effective in overcoming the poisonous action of sodium. N/5000 $CaCl_2$, for example, prevents injury by N/50 NaCl, and this ratio is almost as effective as when N/20 $CaCl_2$ is used with N/50 NaCl.

N/4000 NH_4Cl is toxic to pea and wheat seedlings, the elongation of roots being less than in distilled water. The presence of N/5000 $CaCl_2$ in solution with N/1000 NH_4Cl greatly lowers the harmful action of ammonium ions. No injury results to pea seedlings placed in cultures composed of N/20 $CaCl_2$ + N/100 NH_4Cl.

Salts of ammonium in a full nutrient solution are far less toxic than in distilled water. N/100 NH_4Cl is only slightly injurious with the nutrient solution employed, but with N/25 death of seedlings soon results. The further addition of $CaCl_2$ so that its concentration becomes N/25 or N/100 entirely counteracts the toxicity in the one case and decreases the injury in the other.

As contrasted with their independent action, the poisonous action of sodium and ammonium ions is greatly decreased when present together in solution. This holds when N/50 NaCl is combined with N/100 to N/1000 NH_4Cl, and also when N/1000 NH_4Cl is combined with N/100 to N/1000 NaCl.

Barium ions are very toxic, the elongation of roots of pea seedlings in N/4000 $BaCl_2$ being only about two centimeters. These ions are rendered innocuous by calcium, since growth of seedlings is not retarded when placed in culture solutions composed of N/20 $CaCl_2$ + N/250 $BaCl_2$.

Magnesium and potassium ions also are fairly effective antidotes for barium. On the other hand, barium is a powerful antidote for magnesium and potassium. Thus, the toxicity of N/800 $MgCl_2$ is prevented by the presence of N/6000 $BaCl_2$; the deleterious action of N/25 KCl is overcome by N/2000 $BaCl_2$ and N/1000 $CaCl_2$ (N/1000 $CaCl_2$ being the solvent).

Pure solutions of strontium, even when very dilute, retard the growth of seedlings. Calcium, potassium, sodium, and magnesium each reduces the deleterious action of strontium. Strontium, although present in relatively high dilution, is effective in reducing the toxicity of either potassium, sodium, or magnesium ions.

Mutual antagonism results when potassium and sodium ions are present together in solution. Greater development of seedlings takes place in a solution composed of N/500 KCl + N/50 NaCl than in one composed of N/50 KCl + N/500 NaCl, thus showing that potassium is a more effective antidote for sodium than sodium is for potassium.

The results obtained from the studies of the influence of age of seedlings on toxic and antitoxic action show in general that older seedlings are far more resistant than younger ones to the toxicity of either barium, sodium, strontium, or ammonium ions, and furthermore that calcium is effective in counteracting the toxicity of these ions.

CONCLUSIONS

The chief conclusions to be derived from these experiments are as follows:

1. Each of the following (in the order given) is poisonous to seedlings: Ba, Sr, NH_3, Mg, Na, K.

2. Although mutual antagonism results when cations are present together in solution as follows:

Mg and Sr	Na and K
K and Sr	Na and NH_3
Na and Sr	K and Ba
Mg and Ba	

yet calcium is the most effective of any of the substances studied, in preventing toxic action.

3. Protective action is not confined to the so-called essential nutrients, since, as indicated above, Na, Sr, and Ba (the nonessential ions among those here discussed) possess this property.

4. The favorable results obtained from the application of lime to many types of soils is doubtless due in part to the antidotal relations.

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THE ACTION OF CERTAIN NUTRIENT AND NON-NUTRIENT BASES ON PLANT GROWTH — II

THE TOXICITY OF MANGANESE AND THE ANTIDOTAL RELATIONS BETWEEN THIS AND VARIOUS OTHER CATIONS WITH RESPECT TO GREEN PLANTS *

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Manganese is widely distributed in nature. It occurs in various soil types, in some instances in sufficient amount to be injurious to certain crops. It is likewise present in a variety of plants. The rôle of manganese in plant nutrition is not clearly understood, but the metal is considered to be of importance in connection with the oxidizing enzymes. The salts of manganese have been shown to have a stimulating action on plants when applied to soils in small quantities; but in larger quantities the effect is of course detrimental.

The studies that are included in this report consider two chief relations: (1) the toxicity of manganese in distilled water, in full nutrient solution, and in soil cultures; and (2) the antidotal relations that exist between manganese and each of the bases calcium, potassium, sodium, and magnesium.

OCCURRENCE OF MANGANESE IN SOILS

As stated above, manganese occurs in various soil types. Fertile soils as a rule contain less than one per cent of this element reckoned as oxid. The following table from Wolff (1870–1880) is cited in order to indicate in general the amounts of manganese and iron found in soils:

Kind of soil	Percentage of Mn_3O_4	Percentage of Fe_2O_3
Loam	.135	2.096
Clay	.180	3.173
Sand	.080	1.039
Humus	.042	0.406

* Laboratory of Plant Physiology, Cornell University, Contribution No. 10.

Leclerc (1872) found small amounts of this element in the various soils that he studied, and recent work has shown that some types of soil contain unusually large quantities. The data for soils from certain sections of Hawaii are particularly significant, as the following table from Kelley (1908), for black soils of the Wahiawa district, indicates:

	Percentage
Volatile matter	17.70
Mn_3O_4	9.74
Fe_2O_3	19.65
Al_2O_3	15.50
K_2O	0.83
CaO	1.39
P_2O_5	0.21

OCCURRENCE OF MANGANESE IN PLANTS

The earliest report of the existence of manganese in plants which the writer has been able to obtain is that of Heropath, which Rousset (1909) cites. Heropath found this element in the ash of radish, beet, and carrot. Liebig (1851) reported the presence of manganese in tea. Leclerc (1872) concluded from his analyses that manganese occurs in most species of plants, the percentage being rather high in forest trees. Wolff (1870–1880) also reports analyses which show that manganese is present in the wood, bark, and leaves of various forest trees. Maumené (1884) found that no trace of manganese occurs in the parenchymatous tissue of cabbage leaves, but the veins contain relatively large quantities.

The analyses of Pichard (1898) likewise reveal a wide distribution of manganese in seed plants. The leaves, actively growing parts, and reproductive organs contain the greatest amount.

THE RÔLE OF MANGANESE

The rôle of manganese in plant nutrition is not fully understood, but the researches of Bertrand (1897) established the fact that it is important in the action of the oxidases. Bertrand analyzed the ash of the oxidase-containing material obtained from different samples of laccase, and found the percentage of manganese to be rather high. He studied the oxidizing

power in these samples toward hydroquinone, showing that this power varied with the amount of manganese present. He then extracted the so-called laccase from lucern, at the time of flowering, and found the amount of manganese present to be very slight. The samples did not oxidize hydroquinone. When small amounts of manganese were added oxidation took place. Bertrand's results with the lucern extract are as follows:

Experiment	Material tested	O_2 absorbed (cubic centimeters)
1	Check, manganese alone	0.3
2	Laccase of lucern	0.2
3	Laccase of lucern plus manganese	6.3

When the manganese was replaced by other metals, such as Fe, Al, Sn, Zn, Cu, Mg, and K, the amount of oxygen absorbed was in no case greater than a few tenths of a cubic centimeter.

Bertrand states further that all manganous salts are capable of oxidizing hydroquinone, pyrogallol, paramidophenol, guaiac, and related compounds. His experiments with the action of manganese salts on these compounds lead to the conception of oxidases as special combinations of manganese. In this conception the manganese would be the real active agent, which functions as an activator and a carrier of oxygen.

Voelcker (1903) observed a deeper green color in the tops of wheat grown in cultures to which small amounts of manganese chlorid were added.

Trillat (1904) found that tho addition of manganese to oxidases results in greater activity of these so-called enzymes.

Stoklasa (1911) considers manganese and aluminium to be important in photosynthesis, since they collect mainly in the leaves of plants.

There are numerous reports indicating that manganese may act as a stimulant when applied to soils in small amounts or when present in solution cultures.

Voelcker (1903) reported that in 1902 the addition of various salts of manganese to pots of soil resulted in some cases in a slight increase in

yield of wheat over the product in control cultures. Pots of soil were treated with manganese oxids (MnO_2 and Mn_3O_4), chlorid, iodid, carbonate, sulfate, phosphate, and nitrate, at the rate of two hundred pounds per acre. Increase in yield was obtained from cultures fertilized with phosphate, chlorid, sulfate, and the oxid Mn_3O_4. Parallel experiments were run with barley. The oxids caused no increase in yield; all other salts of manganese resulted in a correspondingly greater increase in yield of barley than of wheat.

The studies were continued in 1903 (1904), when again the oxids of manganese applied to pots of soil at the rate of two hundred pounds per acre showed a beneficial influence on wheat; while with barley it was again found that the oxids of manganese do not produce stimulation.

Loew and Honda (1904) transferred seedlings of *Cryptomeria japonica* from the forest to frames of soil. Small doses of $MnSO_4$ were added to the soil, monthly from May to November inclusive, for two years. The manganese acted as a stimulant, causing an appreciable gain in height and total weight of the trees over those grown in the control frames.

Two plots in a paddy field, each of thirty square meters, were treated with a general fertilizer by Aso (1904). To one was applied in addition two hundred grams of $MnCl_2$. Rice plants were transferred to each plot. Taking the yield of the control plot as a unit, the results obtained from the plot treated with manganese were as follows:

Total yield	1.42
Straw	1.48
Full grains	1.36
Full grains (husked)	1.30

The results show an increase in the grain of approximately one third, by an application of manganese. In order to be able to draw definite conclusions from field work, it seems that more plots should be used in the experiments.

Flax was grown by Fukutome (1908) in pots containing eight kilograms of soil. Each pot received a general fertilizer as follows: 16 grams s perphosphate, 10 grams K_2SO_4, 8 grams $(NH_4)_2$ SO_4, and 8 grams $NaNO_3$. The pots were then treated with special fertilizers. The special fertilizers and the results obtained are indicated in the following table:

Pot	Special fertiliser	Weight of plants, air-dry (grams)
1	Control	10.5
2	.4 gram $MnCl_2+4\ H_2O$	10.7
3	.4 gram $MnCl_2+4\ H_2O$ .4 gram $FeSO_4+7\ H_2O$	12.9
4	.4 gram $FeSO_4+7\ H_2O$	11.6

The manganese and the iron when used alone each causes a small increase in product, but when combined the increase is marked.

Namba (1908) found that the addition of manganese sulfate as a top-dressing to pots of onions containing eight kilograms of soil results in stimulation. The application of greater amounts than .1 gram $MnSO_4$ causes a decrease in stimulating effect.

Loew (1904) found from experiments with pot cultures of soil that manganese stimulates the growth of oats, tobacco, and peas. He found also that the treatment of plots of soil with small quantities of manganese stimulates the growth of radishes, potato, and millet. Manganese is more effective when applied as a top-dressing than when mixed with the soil. It is also better to apply the manganese as several top-dressings than to apply all in one dose.

Bertrand (1905) applied manganese sulfate to a field of oats at the rate of fifty kilograms per hectare. Appreciable stimulation resulted. The gain in the total crop was 22½ per cent. Bertrand considers the action of the manganese to be catalytic.

Labergerie (1908) conducted experiments using manganese as a fertilizer for wheat. His results have been reported as follows:

"In case of wheat on dry sandy soil containing small amounts of lime both the chlorid and the sulphate increased the yield. On a more moist soil the chlorid decreased the yield slightly and the sulphate caused a small increase. In all cases the sulphate was more effective than the chlorid, but both were less effective on wet soil than on dry. . . . . The manganese salts were applied at the rate of 22.27 lbs. of manganese

oxid per acre by dissolving in a considerable volume of water and sprinkling on the soil."

Experiments conducted by Stoklasa (1911) show that manganese and aluminium, when present in small quantities in nutrient solution, each stimulates several species of plants. Stoklasa is of the opinion that these elements are of importance in photosynthesis, inasmuch as they collect mainly in the leaves. Further, the presence of these elements in the culture solution results in the formation of larger leaves.

The nutrient solution employed was made up as follows:

K_2SO_4	1.00 gram
$MgCl_2$	0.50 gram
$NaNO_3$	0.50 gram
$FeSO_4$	0.01 gram
$CaSO_4$	0.05 gram
Distilled water	1 liter

The addition of 2/1000 or 3/1000 atomic weight of either aluminium or manganese to one liter of nutrient solution causes toxic action. The addition of 1/1000 atomic weight of either element results in stimulation; the stimulation is greater when 1/2000 atomic weight of both aluminium and manganese are added to the nutrient solution than when the same concentration of either element is added alone. Stoklasa's results are as follows:

Composition of solution	Dry weight of ten plants (in grams)				
	Wheat	Rye	Oats	Barley	Buck-wheat
Nutrient solution	53.8	78.8	66.2	62.3	15.8
Nutrient solution+1/1,000 at. wt.*Al	56.1	80.9	68.0	67.1	20.2
Nutrient solution+1/1,000 at. wt. Mn	55.9	82.1	68.6	68.8	20.3
Nutrient solution+1/1,000 at. wt. Al+ 1/1,000 at. wt. Mn	50.0	65.2	60.9	61.3	11.8
Nutrient solution+1/2,000 at. wt. Mn	62.8	86.0	70.0	75.2	21.4
Nutrient solution+1/2,000 at. wt. Al	59.8	85.8	71.3	72.8	21.1
Nutrient solution+1/2,000 at. wt. Mn+ 1/2,000 at. wt. Al	82.2	93.6	78.5	89.4	26.5

* Atomic weight.

Sulfate of aluminium and manganese were used in the above experiments. The results were similar, however, when either chlorids, nitrates, or sulfates were employed.

McCallum (1909) reports that the treatment of seed potatoes with manganese chlorid before planting accelerates the formation of tubers. The foliage is not influenced by this treatment.

Brenchley (1910) grew barley to maturity in nutrient solutions to which varying amounts of manganese sulfate were added. The full nutrient solution was made up as follows:

KNO_3	0.50 gram
KH_2PO_4	0.25 gram
$MgSO_4$,	0.25 gram
$CaSO_4$	0.25 gram
NaCl	0.10 gram
$FeCl_3$	Trace
Distilled water	1,000 cubic centimeters

The cultures employed and the dry weights obtained are given in the following table:

Culture	Relation of $MnSO_4$ to amount of solution	Weight of shoots (grams)	Weight of roots (grams)	Weight of grain (grams)	Total weight (grams)
1	1 to 1,000	26.7	4.4	3.8	34.9
2	1 to 100,000	37.1	5.0	6.0	48.1
3	1 to 1,000,000	40.5	5.9	1.7	48.1
4	1 to 5,000,000	47.9	5.8	4.6	58.3
5	1 to 10,000,000	45.9	6.6	6.4	58.9
6	Control	39.1	6.3	7.4	52.8

At the time of harvest the seeds were ripe in culture 3. In culture 2 some seeds were ripe, others were partially ripe, and some were green. Brenchley's conclusions from these experiments are:

"1. The higher concentrations of manganese sulphate have a decided retarding effect upon the ripening of the grain.

"2. While strong solutions of manganese sulphate exert a toxic influence upon the growth of barley, very dilute solutions have a definite stimulative effect."

In another series reported by Brenchley, the nutrient solution employed was about twice as concentrated as that in the former experiment (unfortunately the exact concentration was not reported). In the stronger nutrient solution the presence of manganese in the proportion of 1 part per 10,000 of nutrient solution resulted in stimulation, the toxicity of the manganese being thus reduced.

EXPERIMENTAL STUDIES

The writer has made experiments with manganese from time to time since the autumn of 1910. The results of these experiments are presented in this bulletin. The studies may be grouped as follows:

I. The toxicity of manganese in (A) distilled water, (B) full nutrient solution, and (C) soil cultures; and (D) the relation of previous conditions of growth to toxicity.

II. The influence of light on toxicity of manganese.

III. The antidotal relations that exist between manganese and each of the minerals calcium, potassium, sodium, and magnesium.

Generally Canada field pea seedlings were employed, but in some cases, specially mentioned, wheat seedlings also were used as indicators. The manipulation and the method of experiment, unless otherwise specified were the same as those described previously.

Toxicity of manganese

Many substances at high dilution have a stimulating action toward green plants, but at higher concentrations may be poisonous. Manganese belongs to this class of substances.

Manganese salts in distilled water.— The soluble salts of manganese in distilled water are, of course, more toxic to Canada field pea seedlings than is any nutrient salt. A solution of N/4000 $MnCl_2$ is injurious, and N/2000 $MnCl_2$ prevents root growth entirely. The data presented below were obtained from pea seedlings placed in pure solutions of manganese chlorid:

TABLE 1. EXPERIMENT CONTINUED FOR FIVE DAYS. DATA FOR TEN PLANTS

Composition of solution	Average length of tops (centimeters)	Average length of roots (centimeters)
N/2,000 $MnCl_2$	0	0
N/3,000 $MnCl_2$	Slight	0
N/4,000 $MnCl_2$	1.5	2.5
N/10,000 $MnCl_2$	2.0	3.5
Distilled water	2.0	3.0

From the above table it is seen that a solution of N/3000 $MnCl_2$ prevents root growth, and that N/4000 represents the greatest dilution causing injury during the five-days exposure.

Manganese salts in full nutrient solution.— The poisonous action of manganese toward pea seedlings is greatly reduced when the solvent is a nutrient solution. A number of cultures were set up, in which nutrient solutions were made as follows:*

$Ca(NO_3)_2$	4.0	grams
KH_2PO_4	1.0	gram
KNO_3	1.0	gram
$MgSO_4$	1.0	gram
KCl	0.5	gram
$FeCl_3$	0.1	gram
Distilled water	3.0	liters

In the above nutrient solution the lethal concentration of manganese chlorid is four hundred times as strong as in distilled water.

TABLE 2. EXPERIMENT IN FULL NUTRIENT SOLUTION, CONTINUED FOR THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution	Green weight of tops (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/4 $MnCl_2$	0	0	0
N/5 $MnCl_2$	0	0	0
N/10 $MnCl_2$	0.64	0.5	5.0
N/20 $MnCl_2$	0.85	1.0	8.0
N/50 $MnCl_2$	1.50	1.0	15.0
N/100 $MnCl_2$	2.20	3.0	13.0
N/200 $MnCl_2$	3.20	6.0	13.0
N/500 $MnCl_2$	7.20	14.0	12.0
Nutrient solution	10.40	13.0	10.0

* All full nutrient solutions employed in the experiments that follow, unless otherwise indicated, were composed as given here.

A study of the preceding table and of Fig. 9 reveals some interesting and unusual phenomena. The top growth of the seedlings amounts to only one centimeter in N/50 $MnCl_2$, nutrient solution being the solvent. In N/200 the length of stems is reduced one half, whereas the length of roots in N/50 is greater than in the control. The main roots are longer, but the laterals are shorter and less numerous, than those on the control plants. The presence of N/100 $MnCl_2$ has very little influence on the root development.

Fig. 9.— *Toxicity of $MnCl_2$*
1. N/50 $MnCl_2$ in nutrient solution
2. Control, full nutrient solution

Chlorosis of the leaves is the first indication of an overdose of manganese. The stem and leaf development of seedlings in N/300 to N/500 is normal for the first ten to fifteen days; at about the end of this time the green color begins to fade. In the stronger solutions, as in N/50 to N/200, chlorophyll does not form normally. The leaves in these cultures are chlorotic when they appear and they soon cease growing.

Manganese salts in soil cultures.— Much interest has been manifested in the stimulating action of manganese when applied to soils, as evidenced by the numerous investigations reported. On the other hand, studies of the poisonous action of manganese in soils are fewer in number; therefore the toxicity of this ion has been considered of sufficient importance for further investigation.

In order to determine the toxic action in soil, cultures were made up as indicated in Table 3. One thousand grams of air-dry sandy loam was placed in paraffined pots. To each of these pots was added a solution of $MnCl_2$ (330 cubic centimeters), as given in the table. Melted paraffin was poured over the surface of the soil, and roots of pea seedlings were inserted through holes in the paraffin into the soil below. In general the results obtained are similar to those derived from the full nutrient solutions.

The injurious action of manganese with respect to peas in soil cultures is manifested mainly toward the tops; only relatively concentrated solutions are harmful to the roots of the above plants. When a strong dose of manganese (330 cubic centimeters of N/10 $MnCl_2$ or $MnSO_4$) is applied

to this particular soil, the development of the part of the plants above the surface is 1.5 centimeter, but the root growth is considerable as is shown in the table below. The injury to the roots of the plants is insignificant in the cultures that contain N/50 $MnCl_2$. Slight stimulation results from the addition of a solution of N/500 $MnCl_2$ to this soil.

TABLE 3. EXPERIMENT IN SOIL CULTURES, CONTINUED FOR THIRTY DAYS. DATA FOR TEN PLANTS

Culture	Composition oi solution	Average length of tops (centimeters)	Average length of roots (centimeters)	Weight of roots (grams)	Color of tops
1	N/5 $MnCl_2$	0	Very slight	Not taken	———
2	N/10 $MnCl_2$	1.5	6.0	3.75	Yellow
3	N/25 $MnCl_2$	10.0	8.7	5.00	Yellow
4	N/50 $MnCl_2$	12.5	12.5	8.20	Pale green
5	N/500 $MnCl_2$	16.0	13.0	10.40	Green
6	Control	15.0	12.5	9.10	Green

Chlorosis of the leaves of the plants is noticeable in all the soil cultures except cultures 5 and 6. Chlorophyll apparently does not develop in the leaves of the plants grown in soils dosed as heavily as are cultures 2 and 3. In pot 4 the yellow, or loss of green color of the leaves, is not observable until the plants are ten to fifteen days old. The loss of the green color is doubtless the result of an accumulation of manganese in the leaves; hence, in the soil cultures that contain less concentrated solutions of this element, chlorosis does not appear for several days. The chlorotic leaves do not function in carbon assimilation and death of the plants soon results.

It has been shown recently that this chlorotic action of manganese is of considerable economic importance. Kelley (1908) attributes the "yellows" of pineapples—a condition that is met with in this crop as grown in certain districts in Hawaii — to the abundance of this element. Analyses of the soils where this trouble occurs show the presence of excessive amounts of manganese, as appears on page 172.

Relation of previous conditions of growth to toxicity.— Pea seedlings that have been grown for ten days in distilled water, tap water, and full

nutrient solution, respectively, are much more resistant to the poisonous influence of manganese than are those that are transferred from germinating pans and placed immediately in solutions of manganese. The nature of the medium used in this preliminary treatment — that is, whether distilled water, tap water, or full nutrient solution — has no visible effect on the resisting power of the plants as subsequently subjected to manganese treatment. In these experiments the roots were carefully rinsed with distilled water when they were removed from the tap water and the full nutrient cultures. The data, which are arranged in the following table, were taken five days after the plants were transferred to the solutions of manganese:

TABLE 4. Toxicity of Manganese after Ten Days Growth in Various Media

Ten days in distilled water, then in	Condition	Ten days in tap water, then in	Condition	Ten days in full nutrient solution, then in	Condition
N/25 $MnCl_2$	Dead	N/25 $MnCl_2$	Dead	N/25 $MnCl_2$	Dead
N/50 $MnCl_2$	Dead	N/50 $MnCl_2$	Dead	N/50 $MnCl_2$	Dead
N/75 $MnCl_2$	Dead	N/75 $MnCl_2$	Slight growth, dead	N/75 $MnCl_2$	Dead
N/100 $MnCl_2$	Slight growth, dead	N/100 $MnCl_2$	Slight growth, dead	N/100 $MnCl_2$	Slight growth, dead
N/200 $MnCl_2$	Growing	N/200 $MnCl_2$	Growing	N/200 $MnCl_2$	Growing

The lethal concentration (N/75) of manganese is practically the same for the plants that have been grown in the various media. A comparison of the data in the above table with those in Table 1 (page 179) brings out the fact that plants which have been grown for ten days in either distilled water, tap water, or full nutrient solution are approximately twenty-five times less sensitive to manganese ions than are seedlings which are placed immediately in pure solutions of manganese.

Influence of light on the injurious action of manganese with respect to plants

Certain investigators have indicated that the juice of yellow leaves — those that exhibit chlorosis resulting from the presence of excessive amounts

of manganese—contains more active oxidases than does the juice of normal leaves.

Loew and Sawa (1903), who found that manganous sulfate in certain amounts is injurious to barley, state: "Manganese exerts in moderate quantities an injurious action on plants, consisting of the bleaching out of the chlorophyll. The juice of such plants shows more intense reaction for oxidases and peroxidases than the healthy control plants."

Kelley (1908) has pointed out that the leaves of pineapples grown on soils high in manganese content give more distinct reactions for oxidases with guaiacum and aloin than do the leaves from plants grown on soils containing small amounts of manganese. The writer is not able to state positively that the yellow color of the plants is brought about by actual oxidation of the chlorophyll.

It was noted in preliminary experiments that the manganese ion is especially injurious to plants grown in intense light. Later studies, from experiments conducted in cloudy weather, showed that the harmful action of manganese is retarded somewhat when the plants are grown under the lesser light intensity.

Full nutrient cultures were made in duplicate, to which varying amounts of manganese were added. One set of cultures remained in the light, the other was placed in a darkened aerated chamber; otherwise the conditions were as nearly the same as could be readily maintained. (No apparatus was at hand at the time with which the relative humidity could be regulated. This factor therefore was not controlled.) The results obtained from these experiments appear in Table 5, in Fig. 10, and in the discussion following.

In order to determine more definitely the influence of light on the toxic action of manganese, experiments were made in which plants were kept on the one hand in darkness and on the other hand in normal light. The results are given in Table 5.

It is perfectly clear that manganese is far more injurious to the tops of plants grown under ordinary greenhouse conditions than it is to those grown in darkness. In culture 1, for example, the tops of the plants were dead at the close of the experiment, while those in culture 2 were alive although the leaves were very small and the stems were greatly injured. The lower parts of the stems of the plant in the latter culture were somewhat darkened, as shown in Fig. 10. The leaves of the seed-

TABLE 5. Experiment with Peas, Continued for Fifteen Days. Data for Ten Plants

Culture*	Composition of solution (nutrient solution as the solvent)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Remarks
1	N/25 $MnCl_2$	2.0	2.6	2	Leaves chlorotic from first. Dead at close of experiment
2	N/25 $MnCl_2$	2.0	4.3	10	Leaves little injured, darkened in places
3	N/50 $MnCl_2$	2.2	3.7	5	Leaves yellow from first. Few alive at close of experiment
4	N/50 $MnCl_2$	2.5	6.6	18	Leaves uninjured, stems slightly darkened in places
5	N/100 $MnCl_2$	2.4	4.9	7	Leaves chlorotic after three days. About one half of the leaves dead
6	N/100 $MnCl_2$	2.6	8.2	22	Leaves and stems uninjured
7	Nutrient solution	2.6	9.7	15	Leaves dark green
8	Nutrient solution	2.5	9.7	27	Leaves uninjured

* The odd numbers represent plants grown in light, the even numbers those grown in darkness.

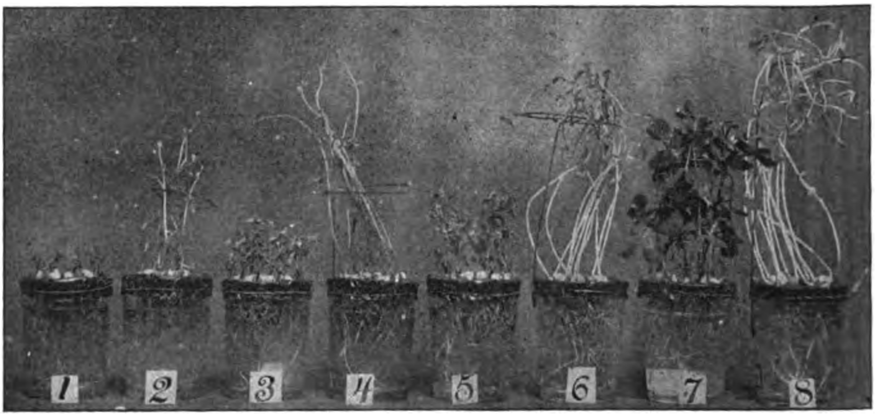

Fig. 10.—*Influence of light on toxicity of manganese*

1. N/25 $MnCl_2$+nutrient solution in light
2. N/25 $MnCl_2$+nutrient solution in darkness
3. N/50 $MnCl_2$+nutrient solution in light
4. N/50 $MnCl_2$+nutrient solution in darkness
5. N/100 $MnCl_2$+nutrient solution in light
6. N/100 $MnCl_2$+nutrient solution in darkness
7. Nutrient solution in light
8. Nutrient solution in darkness

lings in culture 3 became chlorotic after a short time and few remained alive until the close of the experiment; whereas those in culture 4 were uninjured and the stems were far less corroded than those in culture 2. A comparison of the plants grown in culture 6 with those in the control, culture 8, discloses the fact that the toxicity of N/100 $MnCl_2$ toward seedlings grown in the dark is very slight. On the other hand, the toxicity of manganese in ordinary greenhouse light is appreciated when one compares the development of the plants in culture 5 with that in culture 7. The writer is not prepared to offer an explanation of the cause of these results.

An examination of the data in the preceding table and of Fig. 10 further emphasizes the fact that the toxicity of manganese is manifested mainly toward the tops of the plants. The injury to the roots is inappreciable in all the above cultures except 1, 2, and 3. The increased toxicity of manganese in plants grown in light may be due to the greater accumulation of manganese in the leaves, this being brought about by greater transpiration.

Antidotal relations of calcium, potassium, sodium, and magnesium toward manganese

In a previous paper the writer has summarized some of the more important data regarding the antitoxic relations of various mineral elements as cations. He has also added the results obtained from many of his experiments. In connection with the studies on manganese, the writer has investigated the antidotal relations that exist between this element and each of the following: calcium, potassium, sodium, and magnesium.

Calcium and manganese

Calcium and manganese (distilled water).— By means of several series of experiments it has been definitely proved that manganese is rendered innocuous by the addition of calcium. It is to be noted, for example, that a pure solution of N/4000 $MnCl_2$ is toxic to seedlings, but when a stronger solution, N/1000 $MnCl_2$, is mixed with N/2000 $CaCl_2$ the injury due to the manganese is greatly reduced. Protective action exists also with various other combinations of calcium and manganese. The data obtained are set forth in Table 6:

TABLE 6. Experiment with Canada Field Pea, Continued for Thirty Days. Data for Ten Plants

Composition of solution	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$	5.90	6.15	12.05	11.0	13.0
N/25 $CaCl_2$	7.10	5.05	12.15	12.0	15.0
N/100 $CaCl_2$	6.95	4.45	11.40	12.0	12.0
N/500 $CaCl_2$	6.20	4.00	10.20	9.0	13.0
N/1,000 $CaCl_2$	6.65	3.20	9.85	12.0	12.0
N/2,000 $CaCl_2$	5.25	2.47	7.72	10.0	12.0
N/4,000 $CaCl_2$	4.25	2.10	6.35	9.0	10.0
N/10 $CaCl_2$+N/100 $MnCl_2$	2.94	5.06	8.00	7.0	13.0
N/10 $CaCl_2$+N/500 $MnCl_2$	5.46	5.81	11.27	10.0	17.0
N/10 $CaCl_2$+N/1,000 $MnCl_2$	5.12	6.92	12.04	9.0	16.0
N/10 $CaCl_2$+N/2,000 $MnCl_2$	5.15	6.20	11.35	9.0	13.0
N/10 $CaCl_2$+N/4,000 $MnCl_2$	5.76	4.10	9.86	12.0	13.0
N/25 $CaCl_2$+N/1,000 $MnCl_2$	4.52	4.20	8.72	10.0	16.0
N/100 $CaCl_2$+N/1,000 $MnCl_2$	5.56	4.10	9.66	11.0	14.0
N/500 $CaCl_2$+N/1,000 $MnCl_2$	3.75	3.50	7.25	8.0	13.0
N/2,000 $CaCl_2$+N/1,000 $MnCl_2$	3.45	3.05	6.50	6.5	13.0
N/4,000 $CaCl_2$+N/1,000 $MnCl_2$	2.01	2.40	4.41	5.0	10.0
N/1,000 $MnCl_2$*	—	—	—	—	—
N/4,000 $MnCl_2$	1.80	1.64	3.44	5.0	6.5
Distilled water	1.85	1.75	3.60	6.0	7.5

*Weight not taken. Practically no growth. Dead.

As is brought out in the above table, calcium is effective in overcoming the harmful properties of manganese. It is to be noted that solutions of N/10 $CaCl_2$ reduce the deleterious action of various amounts of this mineral element. The greatest development of plants (in mixed solutions) occurs in cultures composed of N/10 $CaCl_2$+N/1000 $MnCl_2$. In N/10 $CaCl_2$+N/100 $MnCl_2$ the toxicity of the manganese toward the tops is not reduced to such an extent as it is toward the roots. The plants in this culture were somewhat chlorotic. It is to be noted further that a very slight amount of calcium (N/4000 $CaCl_2$) reduces the injury caused by N/1000 $MnCl_2$. In no case has the addition of manganese to a solution of calcium resulted in an increased development of plants over that in the corresponding solutions of calcium alone.

The relation of previous conditions of growth to antidotal relations between calcium and manganese.— In order to determine whether the age of seed-

lings modifies the protective action of calcium toward manganese, seedlings were permitted to grow for ten days in pure distilled water and were then transferred to single and mixed solutions of calcium and manganese. Final notes were taken twenty days later. It was thought that changes which would alter the relations of the calcium and manganese might occur in the protoplasm of the cells of the older seedlings. The results obtained show clearly that, although the lethal concentrations of manganese are much higher for older seedlings, calcium counteracts the toxicity of this element in the same manner as before. Slight elongation of the tops takes place when the plants are placed in N/200 $MnCl_2$. A solution of N/100 causes death within three days. The addition of N/10 $CaCl_2$ to the above solutions of manganese results in complete reduction of the toxicity.

FIG. 11.— *Antidotal relations between calcium and manganese. Seedlings in distilled water for ten days, then transferred to*

1. N/10 $CaCl_2$ + N/100 $MnCl_2$
2. N/10 $CaCl_2$
3. Distilled water
4. N/100 $MnCl_2$

TABLE 7. EXPERIMENT CONTINUED FOR TWENTY DAYS. DATA FOR TEN PLANTS

Previous condition of growth	Composition of solution	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
Ten days in distilled water	N/10 $CaCl_2$........	9.45	15	9
	N/10 $CaCl_2$+N/100 $MnCl_2$..........	8.65	13	7
	N/10 $CaCl_2$+N/200 $MnCl_2$..........	8.82	14	8
	N/100 $MnCl_2$......	Dead after three days	——	——
	N/200 $MnCl_2$......	Weight not taken	Slight increase	No increase
	Distilled water.....	2.50	6	6

Full nutrient solution also was employed as a medium in which to grow seedlings for the first ten days. The plants were then placed in cultures containing calcium and manganese separately, and in cultures in which these metals were both in solution. (Precautions were taken to wash carefully the roots of the seedlings when they were removed from the nutrient solution.) Final notes were made twenty days later. The total and the average length of both tops and roots of these plants are greater than in those that were grown for the first ten days in distilled water and then transferred to solutions of calcium and manganese. Here again calcium ions are effective in antidoting manganese ions.

TABLE 8. Experiment Continued for Twenty Days. Data for Ten Plants

Previous condition of growth	Composition of solution	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
Ten days in full nutrient solution	N/10 $CaCl_2$........	18.85	24	11
	N/10 $CaCl_2$+N/50 $MnCl_2$..........	10.35	20	9
	N/10 $CaCl_2$+N/100 $MnCl_2$..........	11.42	22	11
	N/10 $CaCl_2$+N/200 $MnCl_2$..........	16.55	25	10
	N/100 $MnCl_2$......	No further growth	Dead	——
	N/200 $MnCl_2$......	Very slight growth	——	——
	Distilled water.....	11.95	14	8

It may be concluded, from the data obtained from the two series of experiments, that the nature of the substratum (that is, whether distilled water or nutrient solution) in which the seedlings were grown for the first ten days does not influence markedly the antidotal relation of calcium to manganese.

Calcium and manganese (full nutrient solution).— Data have been presented which establish the fact that manganese is much less toxic with respect to seedlings in full nutrient solutions than to seedlings in distilled

water. Nevertheless, the manganese ion is poisonous in cultures that contain all the essential nutrients. A number of cultures were made up in order to determine whether further antidotal relations exist between calcium and manganese when a full nutrient solution is employed as the solvent.

In general, the experiments demonstrate that calcium decreases the

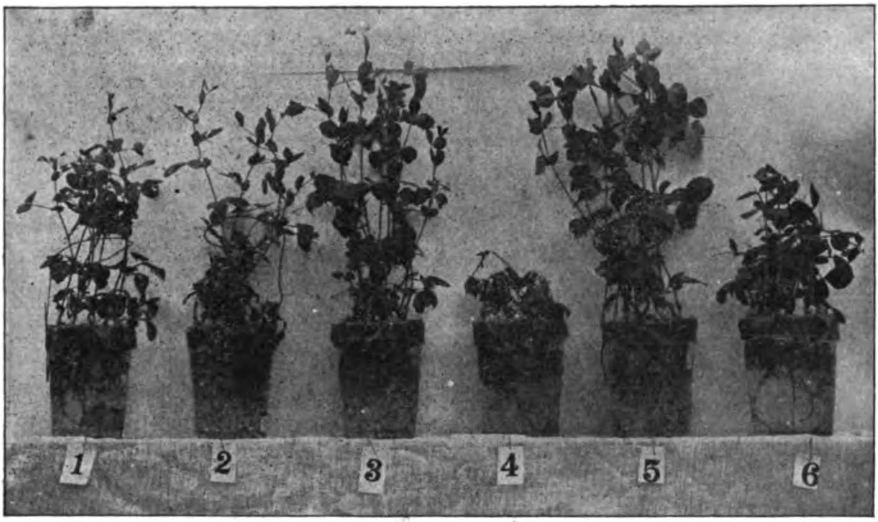

FIG. 12.— *Antidotal relations between calcium and manganese. Plants grown in full nutrient solution for ten days, then transferred to*

1. N/10 $CaCl_2$ + N/50 $MnCl_2$
2. N/10 $CaCl_2$ + N/100 $MnCl_2$
3. N/10 $CaCl_2$ + N/200 $MnCl_2$
4. N/100 $MnCl_2$
5. N/10 $CaCl_2$
6. Distilled water

deleterious action of manganese in the nutrient solution indicated, as might be anticipated from the concentration of the bases. N/50 $MnCl_2$ prevents growth of tops almost entirely. In this culture the lateral roots are shorter and less numerous, but the main roots are longer, than those on the control plants.

The addition of sufficient $CaCl_2$ to make the solution N/10, N/50, N/100, or N/500 of the solvent, results in no reduction of the toxicity of the above solution of manganese.

$N/100$ $MnCl_2$ is likewise very toxic to tops, and to a less extent to roots, of seedlings. Chlorosis of the leaves soon appears in this culture. The presence of either $N/10$ or $N/50$ $CaCl_2$ appreciably counteracts this deleterious action, the loss of green color being then scarcely apparent.

The development of the roots in solutions of $N/200$ $MnCl_2$ is almost as

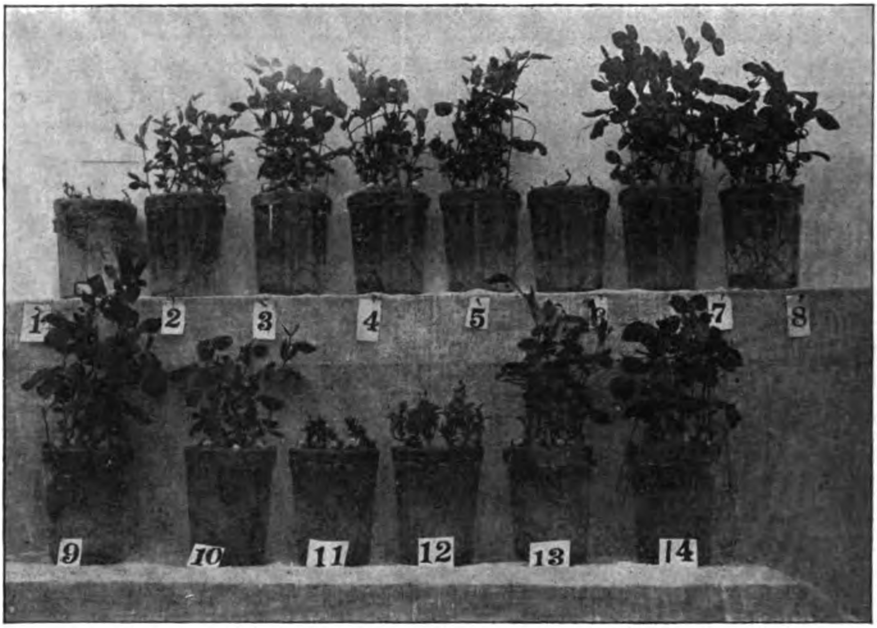

Fig. 13.— *Antidotal relations between calcium and manganese; nutrient solution as the solvent*

1. $N/10$ $CaCl_2$ + $N/50$ $MnCl_2$
2. $N/10$ $CaCl_2$ + $N/100$ $MnCl_2$
3. $N/10$ $CaCl_2$ + $N/500$ $MnCl_2$
4. $N/50$ $CaCl_2$ + $N/500$ $MnCl_2$
5. $N/100$ $CaCl_2$ + $N/500$ $MnCl_2$
6. $N/500$ $CaCl_2$ + $N/50$ $MnCl_2$
7. $N/10$ $CaCl_2$
8. $N/50$ $CaCl_2$
9. $N/100$ $CaCl_2$
10. $N/500$ $CaCl_2$
11. $N/50$ $MnCl_2$
12. $N/100$ $MnCl_2$
13. $N/500$ $MnCl_2$
14. Nutrient solution

extensive as in the control cultures. The length of the stems is about one half that of those grown in the nutrient solution. The presence of $N/500$ $CaCl_2$ results in a slight increase in elongation of the stems. The detailed data obtained appear in Table 9:

TABLE 9. EXPERIMENT CONTINUED FOR THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution (full nutrient solution as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/10 $CaCl_2$+N/50 $MnCl_2$	0.50	1.46	1.96	1	6
N/10 $CaCl_2$+N/100 $MnCl_2$	5.05	4.95	10.00	11	8
N/10 $CaCl_2$+N/500 $MnCl_2$	7.36	6.35	13.71	13	11
N/50 $CaCl_2$+N/50 $MnCl_2$	0.45	——	——	1	15
N/50 $CaCl_2$+N/100 $MnCl_2$	2.55	5.55	8.10	4	12
N/100 $CaCl_2$+N/50 $MnCl_2$	0.35	1.75	2.10	1	11
N/100 $CaCl_2$+N/100 $MnCl_2$	2.55	4.20	6.75	5	10
N/100 $CaCl_2$+N/500 $MnCl_2$	7.19	4.85	12.04	13	11
N/500 $CaCl_2$+N/50 $MnCl_2$	0.37	2.30	2.67	1	12
N/500 $CaCl_2$+N/100 $MnCl_2$	2.10	4.90	7.00	5	14
N/500 $CaCl_2$+N/200 $MnCl_2$	3.15	4.60	7.75	7	12
N/1,000 $CaCl_2$+N/100 $MnCl_2$	1.60	4.26	5.86	2	13
N/1,000 $CaCl_2$+N/200 $MnCl_2$	2.10	3.80	5.90	4	13
N/50 $MnCl_2$	1.00	2.95	3.95	2	15
N/100 $MnCl_2$	2.25	4.00	6.25	4	13
N/200 $MnCl_2$	2.70	4.45	7.15	6	13
N/500 $MnCl_2$	6.90	4.65	11.55	14	12
N/10 $CaCl_2$	9.75	7.15	16.90	16	10
N/50 $CaCl_2$	9.10	5.60	14.70	12	12
N/100 $CaCl_2$	10.85	6.15	17.00	15	10
N/500 $CaCl_2$	10.20	5.45	15.65	14	16
N/1,000 $CaCl_2$	9.90	4.90	14.80	14	9
Full nutrient solution	10.40	5.20	15.60	13	10

Calcium and manganese (soil cultures).— It is of special interest and of great economic importance to ascertain whether the toxicity of manganese in soils may be reduced by the application of lime. The writer has found from repeated experiments that large applications of lime to pots of soil overdosed with manganese result in a more vigorous development of the plants in the pots.

In these experiments glass tumblers were used as containers. In each tumbler was placed 250 grams of air-dry sandy loam, to which was added 80 cubic centimeters of the solutions employed. Ten pea seedlings were used in each tumbler, the roots growing into the moist soil through a hole in the paraffin that had previously been applied to the surface of the soil. Subsequently the number of plants was reduced to five in each tumbler. The water lost from the soil was replaced from time to time

by the addition of distilled water. After thirty days the experiments were discontinued. The results obtained appear in Table 10:

TABLE 10. EXPERIMENT CONTINUED FOR THIRTY DAYS
(The data observed for five plants were calculated for ten plants, so that a comparison might be made with other experiments)

Composition of solution		Total weight of tops (grams)	Total weight of roots (grams)	Average length of tops (centimeters)	Remarks
N/25 $MnCl_2$	(a)	Too dry	3.2	6	Tops dead
	(b)	to weigh	2.3	9	
N/50 $MnCl_2$	(a)	7.0	12.2	24	Leaves slightly chlorotic
	(b)	8.5	10.0	22	
Distilled water	(a)	9.0	9.0	27	Color good
	(b)	10.0	——	29	
N/25 $CaCl_2$+N/25 $MnCl_2$	(a)	5.0	5.4	18	Color fair
	(b)	5.6	4.1	20	
N/50 $CaCl_2$+N/50 $MnCl_2$	(a)	9.2	8.2	28	Color fair
	(b)	9.8	8.6	25	
N/25 $CaCl_2$	(a)	8.0	10.2	26	Color good
	(b)	6.4	7.8	25	
N/50 $CaCl_2$	(a)	8.1	10.0	28	Color good
	(b)	——	——	——	

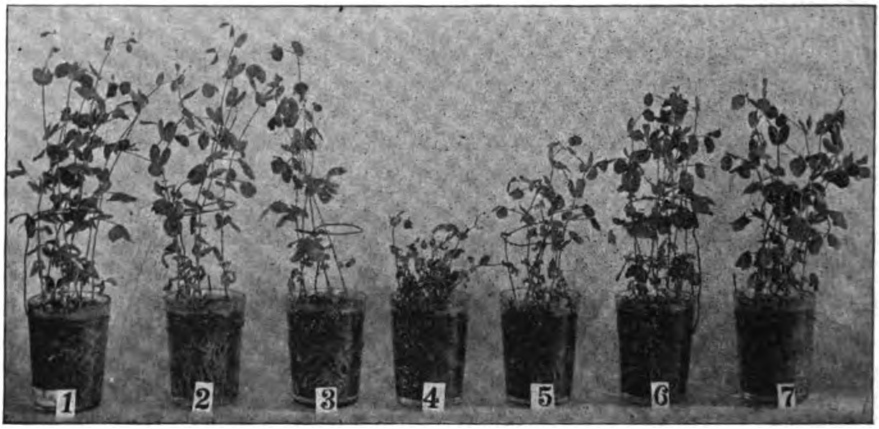

FIG. 14.— *Antidotal relations between calcium and manganese in soil cultures*

1. N/50 $CaCl_2$
2. N/50 $CaCl_2$+N/50 $MnCl_2$
3. N/50 $MnCl_2$
4. N/25 $MnCl_2$
5. N/25 $MnCl_2$+N/25 $CaCl_2$
6. N/25 $CaCl_2$
7. Distilled water

The addition of N/25 $MnCl_2$ to this particular soil results in great injury to pea seedlings. The growth of tops is only 6 centimeters and the root growth is likewise depressed. The presence of N/25 $CaCl_2$ reduces the injury from the manganese, as the average growth of tops in this culture is 19 centimeters and the root growth is also more extensive. These results are at variance with those obtained by pineapple-growers in Hawaii, as Kelley (1908) reports that the addition of lime or other fertilizers is not effective in counteracting the injury resulting from manganese.

Potassium and manganese

Potassium and manganese (*distilled water*).— Since calcium is relatively effective in antidoting manganese, it is of interest to ascertain whether other metals as cations counteract this injurious action. By means of several sets of experiments it has been determined that mutual antagonism exists between manganese and each of the following: potassium, sodium, and magnesium. N/500 $MnCl_2$ prevents growth of wheat seedlings and N/2000 is extremely toxic. This deleterious action is overcome by the presence of N/50 KCl. A weaker solution of potassium, N/500, is antagonistic toward manganese, but to a less extent than more concentrated solutions.

N/50 KCl is very injurious to roots of wheat seedlings. The presence of either N/500, N/2000, or N/5000 $MnCl_2$ counteracts this toxicity. An examination of Table 11 bears out the above statements:

TABLE 11. EXPERIMENT WITH WHEAT, CONTINUED FOR THIRTY DAYS. DATA FOR EIGHT PLANTS

Composition of solution	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 KCl	0.65	6	1
N/50 KCl+N/500 $MnCl_2$	0.85	8	3
N/50 KCl+N/2,000 $MnCl_2$	1.50	9	4
N/50 KCl+N/5,000 $MnCl_2$	1.20	11	3
N/500 KCl+N/2,000 $MnCl_2$	0.80	9	2
N/2,000 $MnCl_2$	0	2	0
Distilled water	0.55	6	4

Potassium and manganese (*N/1000 $CaCl_2$*).— Under ordinary greenhouse conditions pea seedlings, in distilled water or in full nutrient solu-

tion lacking calcium, rarely grow to a height of more than two inches. However, if calcium is present, even in relatively small amounts, growth proceeds for about four weeks. The ash of pea seeds contains relatively small amounts of calcium, but the magnesia content is high. This unbalanced condition probably accounts for the demands for calcium in the above instances. Taking cognizance of these facts, N/1000 $CaCl_2$ was used as the solvent in making up cultures in order to determine whether, under such circumstances, antidotal relation may be recognized to exist between potassium and manganese. The solutions used and the results obtained appear in the following table:

TABLE 12. Experiment Continued for Thirty Days. Data for Ten Plants

Composition of solution (N/1000 $CaCl_2$ as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 KCl	3.75	5.05	6	9
N/50 KCl+N/100 $MnCl_2$	0.45	2.01	1	6
N/50 KCl+N/500 $MnCl_2$	4.10	4.08	8	8
N/50 KCl+N/1,000 $MnCl_2$	5.10	4.25	9	10
N/500 KCl+N/1,000 $MnCl_2$	3.35	4.02	7	10
N/1,000 KCl+N/1,000 $MnCl_2$	3.16	3.15	6	12
N/1,000 $MnCl_2$	2.45	3.35	5	10
N/1,000 $CaCl_2$	5.01	3.35	8	10

Fig. 15.— *Antidotal relations between potassium and manganese; N/1000 $CaCl_2$ as the solvent*

1. N/1000 $CaCl_2$
2. N/50 KCl
3. N/50 KCl+N/100 $MnCl_2$
4. N/50 KCl+N/500 $MnCl_2$
5. N/50 KCl+N/1000 $MnCl_2$
6. N/500 KCl+N/1000 $MnCl_2$
7. N/1000 $MnCl_2$

The root development of the plants in the culture composed of N/1000 $CaCl_2$+N/50 KCl is far more abundant than in the control, N/1000 $CaCl_2$, but the top growth is less. It is thus seen that N/50 KCl depresses the growth of the stems. When either N/500 or N/1000 $MnCl_2$ is present with N/50 KCl, in the presence of the weak calcium, the retarding action of the potassium is entirely overcome.

Manganese is antidoted by potassium, as is shown by Fig. 15 and by the data in Table 12. Slight antagonism results in cultures composed of N/50 KCl+N/100 $MnCl_2$+N/1000 $CaCl_2$. Greater protective action exists when the above amount of potassium is present with either N/500 or N/1000 $MnCl_2$. Considering the top growth of seedlings, mutual antagonism exists between potassium and manganese; considering root growth alone, however, potassium has a protective action toward manganese.

Potassium and manganese (full nutrient solution).— The further addition of potassium to a full nutrient solution one tenth as strong as the one employed in the previous experiments, lowers the deleterious action of either N/100 or N/500 $MnCl_2$. The further addition of potassium (N/20 KCl) to the nutrient solution also results in an increase of root development, the lateral roots especially being longer and more numerous than those of the control plants. On the other hand, the top growth is retarded somewhat. The results obtained from these experiments appear in Table 13:

TABLE 13. EXPERIMENT CONTINUED FOR THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution (full nutrient solution as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/20 KCl	4.85	4.26	9.11	10.0	5.6
N/20 KCl+N/100 $MnCl_2$	1.45	1.68	3.13	6.0	7.5
N/20 KCl+N/500 $MnCl_2$	4.60	3.50	8.10	9.0	6.0
N/100 $MnCl_2$	0.85	1.35	2.20	1.5	5.0
N/500 $MnCl_2$	2.15	3.20	5.35	6.0	7.0
Full nutrient solution	5.15	3.55	8.70	13.0	4.0

Sodium and manganese

Sodium and manganese (distilled water).— Sodium and manganese are mutually antagonistic in distilled water. Solutions of N/50 NaCl reduce the poisonous action of solutions of manganese ranging in concentration from N/500 to N/5000. The toxicity of both sodium and manganese toward wheat seedlings is not evident when the salts of these metals are present in solution as N/50 NaCl+N/5000 $MnCl_2$, and the amount of injury is greatly lessened in the other combinations employed. The data obtained are summarized in Table 14:

TABLE 14. Experiment with Wheat, Continued for Thirty Days. Data for Eight Plants

Composition of solution	Total weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
N/50 NaCl+N/500 $MnCl_2$	0.36	2.0	1.0
N/50 NaCl+N/1,000 $MnCl_2$	0.80	5.5	2.0
N/50 NaCl+N/3,000 $MnCl_2$	0.90	6.0	8.0
N/50 NaCl+N/5,000 $MnCl_2$	0.92	9.0	9.0
N/50 NaCl	Very slight	1.0	0
N/3,000 $MnCl_2$	0.48	3.0	2.0
N/5,000 $MnCl_2$	0.55	4.0	3.0
Distilled water	0.92	9.0	4.0

Magnesium and manganese

Magnesium and manganese (N/1000 $CaCl_2$).— The fact that magnesium and manganese are very toxic in pure solutions makes it especially interesting to ascertain the results when these are combined. The development of pea seedlings is greater in cultures containing both these harmful substances than in cultures in which only one is present, again indicating mutual antagonism. N/500 and N/1000 $MnCl_2$, for example, are injurious to the tops. This injury is prevented by the presence of N/50, N/100, or N/200 $MgCl_2$; moreover, the development of the plants in these solutions is more extensive than in the corresponding solutions of magnesium.

Magnesium and manganese (full nutrient solution).— In this series, as in the preceding one, magnesium effectively counteracts the injurious action of manganese toward pea seedlings. It is to be noted, for example, that solutions of N/200 $MnCl_2$ are very toxic; the leaves of seedlings

TABLE 15. EXPERIMENT CONTINUED FOR TWENTY-FIVE DAYS. DATA FOR EIGHT PLANTS

Composition of solution ($N/1000\ CaCl_2$ as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Total green weight (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)
$N/50\ MgCl_2$	2.10	1.20	3.30	6.0	7.0
$N/100\ MgCl_2$	2.75	1.84	4.59	8.0	9.5
$N/200\ MgCl_2$	3.62	2.04	5.66	13.0	12.0
$N/50\ MgCl_2+N/500\ MnCl_2$	4.80	2.40	7.20	13.5	12.5
$N/100\ MgCl_2+N/500\ MnCl_2$	4.75	2.50	7.25	12.0	13.0
$N/200\ MgCl_2+N/500\ MnCl_2$	4.00	2.30	6.30	11.0	13.0
$N/100\ MgCl_2+N/1,000\ MnCl_2$	4.20	2.00	6.20	16.0	14.0
$N/200\ MgCl_2+N/100\ MnCl_2$	4.90	2.50	7.40	14.0	14.0
$N/500\ MnCl_2$	1.75	1.65	3.40	7.0	12.0
$N/1,000\ MnCl_2$	2.54	1.75	4.29	10.0	13.0
$N/1,000\ CaCl_2$	3.57	1.70	5.27	12.0	10.0

grown in these cultures become chlorotic and the top growth is reduced. The addition of $N/20\ MgCl_2$ prevents this injury. Moreover, the presence of $N/50\ MgCl_2$ prevents chlorosis which appears in plants grown in solutions of $N/500\ MnCl_2$.

TABLE 16. EXPERIMENT CONTINUED FOR TWENTY-FIVE DAYS. DATA FOR EIGHT PLANTS

Composition of solution (full nutrient solution as the solvent)	Green weight of tops (grams)	Green weight of roots (grams)	Average length of tops (centimeters)	Average length of roots (centimeters)	Remarks
$N/200\ MnCl_2$	3.10	2.60	8.0	10.0	Lateral roots long, leaves yellow
$N/500\ MnCl_2$	6.20	3.00	15.0	12.0	Lateral roots long, leaves yellowish
$N/50\ MgCl_2$	7.15	3.50	13.0	14.0	Lateral roots short, leaves dark green
$N/20\ MgCl_2+N/200\ MnCl_2$	6.05	2.80	17.5	18.0	Lateral roots short, color of leaves good
$N/50\ MgCl_2+N/200\ MnCl_2$	4.10	2.75	16.0	16.0	Lateral roots long, color of leaves pale
$N/50\ MgCl_2+N/500\ MnCl_2$	7.27	3.40	17.0	13.0	Lateral roots medium, color of leaves good
Nutrient solution	7.27	3.60	14.0	13.0	Lateral roots medium, color of leaves good

CONCLUSIONS

Pure solutions of manganese salts are extremely poisonous to pea and wheat seedlings. The degree of toxicity is greatly reduced by full nutrient solutions and by soil cultures.

The injurious action of the manganese ion is manifested mainly toward the tops of plants. Chlorosis of the leaves is the first indication of an overdose of manganese.

Manganese is less injurious to plants grown in the dark than to those grown in the light.

Calcium, potassium, sodium, and magnesium ions are each effective in counteracting the poisonous action of manganese. Mutual antagonism exists between the manganese ion and each of the following: potassium, sodium, and magnesium.

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THE ACTION OF CERTAIN NUTRIENT AND NON-NUTRIENT BASES ON PLANT GROWTH — III

TOXICITY OF VARIOUS CATIONS*

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HISTORICAL

As a result of numerous investigations that have been made on antagonistic action and toxic action, there are available for green plants many data with respect to the relative toxicity of certain nutrient and non-nutrient substances. In the first part of this paper extensive data have been reviewed and presented regarding the modification of toxic action in mixed solutions, especially the effects of the cations, one on another, of the substances constituting the nutrient solution. Furthermore, the experiments of Guthrie and Helms (1903–1905), Kanda (1904), Cameron and Breazeale (1904), Dandeno (1904), Harter (1905), True and Oglevee (1905), Jensen (1907), Magowan (1908), Duggar (1911), and others have shown that, as a rule, substances are far less toxic in the presence of inert solid particles, sand, or soil, than when present in pure solutions.

The reduction of toxicity by quartz sand, soil, and other solid particles has been attributed to the following factors: chemical reactions between the solute and the solid particles, resulting in the formation of less toxic substances; adsorption of the molecules or ions of the toxic agent; and obstruction to the free movement of the molecules or ions in solution.

The reduction of the toxicity of deleterious agents when present in nutrient solutions may be attributed in part to chemical reactions that result in the formation of less toxic substance, to a decrease in penetrability of the protoplasmic membrane, and perhaps to other important factors.

EXPERIMENTAL

The writer has made comparative studies of the poisonous action of the chlorids of calcium, potassium, sodium, magnesium, ammonium, barium, strontium, and manganese, in distilled water, in full nutrient

* Laboratory of Plant Physiology, Cornell University, Contribution No. 11.

solution, and in soil cultures. The concentrations in which no further elongation of seedlings takes place, those in which slight growth occurs, and those that result in no injury to seedlings, have been determined. As a rule, Canada field pea seedlings were employed as indicators, although in some instances wheat seedlings also were used.

The methods of experiment and manipulation were the same as those described in Part I.

Toxicity of calcium

Each of the other elements studied is far more toxic than calcium. In fact, calcium ions do not prohibit growth of pea and wheat seedlings at concentrations much below those that result in plasmolysis, although at the higher concentrations some injury ensues. The results that were obtained from the experiments are summarized in the tables immediately following:

TABLE 1. Experiment with Canada Field Pea. Duration, Ten Days. Data for Ten Plants

Composition of solution	Pea		Wheat	
	Increase in length of tops	Increase in length of roots	Increase in length of tops	Increase in length of roots
Distilled water as the solvent				
N/2 $CaCl_2$	None	None	None	None
N/3 $CaCl_2$	Slight	Slight	None	None
N/5 $CaCl_2$	Slight	Slight	Slight	Slight
N/10 $CaCl_2$	Good	Good	Good	Good
Distilled water	Good	Good	Good	Good
Full nutrient solution as the solvent				
N/2 $CaCl_2$	None	None	None	None
N/4 $CaCl_2$	Slight	Slight	Slight	Slight
N/5 $CaCl_2$	Slight	Slight	Slight	Slight
N/10 $CaCl_2$	Good	Good	Good	Good
Nutrient solution	Good	Good	Good	Good
Soil cultures*				
N/1 $CaCl_2$	None	None	None	None
N/2 $CaCl_2$	None	None	None	None
N/4 $CaCl_2$	2.0 cm.	2.5 cm.	5.1 cm.	2.5 cm.
N/5 $CaCl_2$	4.0 cm.	5.1 cm.	10.2 cm.	6.3 cm.
Water	5.1 cm.	5.1 cm.	———	———

* Air-dry soil, to which was added a quantity of the solution equal to thirty per cent of its dry weight. The soil employed was a sandy loam containing 3.5 per cent volatile matter.

Toxicity of potassium

Potassium is appreciably more toxic than calcium, but less injurious than the other ions that the writer has studied. As is the case with calcium, the injury is reduced when potassium is present in full nutrient solution and in soil cultures. Slight elongation of tops occurs in solutions composed of N/10 KCl, but no appreciable root growth appears in solutions stronger than N/50 KCl. Cameron and Breazeale (1904) obtained similar results from other substances; for instance, they found that "the concentration required to kill a seedling or disorganize an entire radicle varies widely from that required to completely hinder any growth or elongation, or that which will permit some elongation . . . . . ." The results of the writer's studies appear in Table 2:

TABLE 2. EXPERIMENT WITH WHEAT AND PEA SEEDLINGS, CONTINUED FOR TEN DAYS. DATA FOR TEN PLANTS

Composition of solution	Pea		Wheat	
	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)
Distilled water as the solvent				
N/5 KCl	0	0	0	0
N/10 KCl	0.25	0	0	0
N/20 KCl	0.50	0	6.00	0
N/30 KCl	1.00	0	6.00	0
N/50 KCl	3.00	Slight	7.00	2.00
N/200 KCl	6.00	7.50	6.50	7.00
Distilled water	6.00	7.00	7.00	6.00
Full nutrient solution as the solvent				
N/4 KCl	0	0	2.50	0
N/5 KCl	2.50	Slight	5.00	1.50 No branches
N/7 KCl	5.00	3.75	6.25	6.25 Few branches
N/10 KCl	6.25	7.50	7.50	7.50 Slightly branched
N/50 KCl	7.50	10.00	8.75	11.25
Nutrient solution	6.25	8.75	7.50	10.00 Branched

Toxicity of sodium

Sodium ions in distilled water are somewhat more deleterious to pea and wheat seedlings than are potassium ions. No top growth results in

solutions stronger than N/30 NaCl, whereas slight development of tops occurs in cultures containing N/10 KCl. The lethal concentration of sodium for roots is just below N/75.

TABLE 3. Experiment with Pea and Wheat Seedlings, Continued for Ten Days. Data for Ten Plants

Composition of solution	Pea		Wheat	
	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)
Distilled water as the solvent				
N/5 NaCl	0	0	0	0
N/10 NaCl	0	0	0	0
N/20 NaCl	0	0	0	0
N/30 NaCl	0.25	0	0	0
N/50 NaCl	0.50	0	1.00	0
N/75 NaCl	3.00	3.00	2.00	3.50
Distilled water	6.00	7.00	7.00	8.00
Full nutrient solution as the solvent				
N/3 NaCl	0	0	—	—
N/4 NaCl	0	0	0	0
N/5 NaCl	1.00	2.00	1.00	2.00
N/10 NaCl	6.00	7.00	9.00	8.00
Nutrient solution	7.50	8.50	9.00	10.00
Soil cultures				
N/1 NaCl	0	0	—	—
N/2 NaCl	0	0	—	—
N/3 NaCl	—	—	—	—
N/5 NaCl	Slight	Slight	—	—
N/10 NaCl	6.50	7.00	—	—
Distilled water	6.00	6.50	—	—

Harter (1905) gives .054 N as the average limit of pure solutions of sodium chlorid for several varieties of wheat. In his experiments the roots of the seedlings were in contact with the solutions only twenty-four hours. This undoubtedly accounts for the higher values that he obtained.

Toxicity of magnesium

Magnesium has long since been considered as injurious to plants when calcium is absent from the media or present in relatively small amounts. It is to be noted that the lethal concentration of magnesium ions in distilled water with respect to the roots of seedlings is at a dilution several times greater than that of either sodium or potassium. Wheat seedlings are more resistant to this element than are pea seedlings. No root growth occurs with peas in solutions composed of N/500 $MgCl_2$, but slight elongation of the roots of wheat seedlings takes place. The following data verify the above statements:

TABLE 4. EXPERIMENTS WITH PEA AND WHEAT SEEDLINGS, CONTINUED FOR THIRTY DAYS. DATA FOR TEN PLANTS

Composition of solution	Pea		Wheat	
	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)
Distilled water as the solvent				
N/50 $MgCl_2$	2.0	0	0.5	0
N/100 $MgCl_2$	2.0	0	4.0	0
N/300 $MgCl_2$	3.0	0	6.0	0
N/500 $MgCl_2$	3.5	0	7.0	2.0
N/1,000 $MgCl_2$	5.0	Slight-dead	7.0	6.0
Distilled water	6.0	7.0	7.0	6.0
Full nutrient solution as the solvent				
N/4 $MgCl_2$	0	0	0	0
N/5 $MgCl_2$	2.0	Slight	Slight	1.0
N/6 $MgCl_2$	3.0	1.5	3.0	4.0
N/10 $MgCl_2$	6.0	7.0	7.0	8.0
Nutrient solution	7.5	8.5	9.0	10.0

In working with several varieties of wheat, Harter (1905) ascertained that considerable differences exist between the varieties in their power to resist the poisonous action of various ions. In determining the limit for any one variety, he took as the lethal concentration the one in which about one half of the seedlings lived and one half died after remaining in the solutions for twenty-four hours. The average lethal concentration

for magnesium chlorid was found to be N/110 (.0093 N), which is much more concentrated than the values obtained by the writer for seedlings that remained in the solutions for ten days.

Toxicity of ammonium

Roots of both pea and wheat seedlings are especially sensitive to ammonium in distilled water, slight elongation of the roots of either taking place in N/1000 NH_4Cl. However, much stronger solutions are required in order to prevent top growth; for example, top growth is evident in solutions of N/20 NH_4Cl.

TABLE 5. Experiments with Pea and Wheat Seedlings. Duration, Ten Days. Data for Ten Plants

Composition of solution	Pea		Wheat	
	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)
Distilled water as the solvent				
N/5 NH_4Cl	0	0	0	0
N/10 NH_4Cl	0	0	0	0
N/20 NH_4Cl	0.5	0	1.0	0
N/30 NH_4Cl	1.0	0	1.5	0
N/50 NH_4Cl	1.0	0	3.0	0
N/100 NH_4Cl	2.0	Very slight	5.0	Very slight
N/500 NH_4Cl	3.0	Very slight	8.0	2.0
N/1,000 NH_4Cl	3.0	Very slight	8.0	2.5
Distilled water	6.0	7.5	7.0	6.5
Full nutrient solution as the solvent				
N/3 NH_4Cl	0	0	—	—
N/4 NH_4Cl	Slight	1.5	—	—
N/5 NH_4Cl	Slight	3.0	—	—
N/10 NH_4Cl	2.5	4.0	—	—
Nutrient solution	7.5	8.5	—	—
Soil cultures				
N/3 NH_4Cl	0	0	—	—
N/5 NH_4Cl	3.0	2.5	—	—
N/10 NH_4Cl	5.5	4.0	—	—
Distilled water	7.0	7.5	—	—

Toxicity of barium

The writer has presented data by means of which it was demonstrated that barium ions when present in distilled water are extremely deleterious to pea seedlings. The data given below lend further emphasis to this point. Although N/4000 $BaCl_2$ is the lethal concentration for roots of pea seedlings, great injury results from far more dilute solutions. It will be noted in Table 6 that N/10,000 $BaCl_2$ retards root development. In a full nutrient solution the same root retardation is secured only with N/20 $BaCl_2$. The toxicity of barium is of course greatly depressed when present in full nutrient solutions or in soil cultures.

TABLE 6. EXPERIMENT WITH CANADA FIELD PEA SEEDLINGS. DURATION, TEN DAYS. DATA FOR TEN PLANTS

Composition of solution	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)
Distilled water as the solvent		
N/3,000 $BaCl_2$	2.5	0
N/4,000 $BaCl_2$	4.0	0
N/5,000 $BaCl_2$	4.5	Slight
N/10,000 $BaCl_2$	6.0	2.5
Distilled water	6.0	7.5
Full nutrient solution as the solvent		
N/6 $BaCl_2$	0	0
N/10 $BaCl_2$	0	0
N/20 $BaCl_2$	2.0	2.5
N/100 $BaCl_2$	6.0	5.0
Control	7.5	8.5

Toxicity of strontium

Strontium exhibits a rather unusual behavior toward seedlings. Comparatively dilute solutions in distilled water are extremely injurious, but very strong solutions are required in order to prevent growth. For example, N/2000 $SrCl_2$ greatly retards the growth of the roots of pea seedlings, but roots are not killed when placed in solutions of N/7 $SrCl_2$, slight development resulting.

TABLE 7. Experiment with Canada Field Pea Seedlings. Duration, Ten Days. Data for Ten Plants

Composition of solution (Distilled water as the solvent)	Increase in length of tops (centimeters)	Increase in length of roots (centimeters)
N/5 $SrCl_2$	0	0
N/7 $SrCl_2$	0.6	Slight
N/10 $SrCl_2$	0.6	Slight
N/500 $SrCl_2$	2.5	Slight, no lateral roots
N/1,000 $SrCl_2$	5.0	1.25 No lateral roots
N/2,000 $SrCl_2$	7.5	2.50 Lateral roots very short
N/5,000 $SrCl_2$	7.5	5.00 Lateral roots medium
Distilled water	7.5	6.25 Lateral roots medium

Little discussion of the results obtained with full nutrient and soil cultures is required, since the results, with the exception of strontium and barium, are so nearly uniform. The lethal concentrations of the various bases are practically identical, namely, N/3 to N/5. As a rule the seedlings withstand slightly stronger solutions when present in soil cultures. Of course, with longer duration of the experiments many concentrations that have not proved injurious would become so.

INFLUENCE OF PREVIOUS CONDITIONS OF GROWTH ON THE RESISTANCE TO THE TOXICITY OF VARIOUS IONS

Pea seedlings were grown for ten days in distilled water, full nutrient solution, and tap water, in order to determine whether age and the composition of the media influenced the resistance of seedlings to various ions. At the end of this period the seedlings were removed, carefully washed with distilled water, and placed in pure solutions of various salts. Final notes were taken three days later. In general it may be said that older seedlings are more resistant than young ones; for example, the roots of young seedlings are killed by N/50 NaCl, whereas the roots of older seedlings withstand much stronger solutions. The composition of the media has little influence on the resistance of the seedlings, as may be seen from the data summarized in Table 8.

TABLE 8. INFLUENCE OF PREVIOUS CONDITIONS ON TOXICITY

Distilled water	Full nutrient solution	Tap water
$NaCl$	$NaCl$	$NaCl$
N/10 dead N/15 dead N/20 wilting (slight growth) N/50 good	N/10 dead N/15 dying N/20 growing	N/10 dead N/15 dying N/20 growing
KCl	KCl	KCl
N/5 dead N/7 dead N/10 growing	N/5 dead N/7 dead (slight growth) N/10 growing	N/5 dead N/7 dead (slight growth) N/10 growing
NH_4Cl	NH_4Cl	NH_4Cl
N/20 dead N/40 dying N/70 growing	N/20 dead N/25 tips of leaves dying N/50 growing	N/10 dead N/25 growing—injured N/50 growing
$CaCl_2$	$CaCl_2$	$CaCl_2$
N/3 dead N/5 growing N/10 good	N/3 dead N/5 growing N/10 good	N/3 dead N/5 growing N/10 good
$MgCl_2$	$MgCl_2$	$MgCl_2$
N/10 dead N/20 dead N/50 good	N/10 dead N/20 dying N/40 growing	N/10 dead N/20 dying N/40 growing
$MnCl_2$	$MnCl_2$	$MnCl_2$
N/25 dead N/50 dead N/100 dying N/200 slight growth	N/25 dead N/50 tops dead, roots medium N/75 tops injured, roots medium N/100 tops injured, roots medium	N/25 dead N/75 tops dead, roots alive N/100 tops slight growth dead; roots alive N/200 tops not injured
$BaCl_2$	$BaCl_2$	$BaCl_2$
N/100 dead N/300 dead N/500 slight growth	N/100 dead N/300 slight growth N/500 growing	N/100 dead N/200 dead N/300 slight growth N/500 growing

INFLUENCE OF CERTAIN SALTS ON GERMINATION OF CANADA FIELD PEA SEED

Experiments have been conducted also to determine the influence of various substances on the germination of pea seed. These experiments comprised two series: in the first series the effect of steeping the seed in pure solutions of the substances was determined; in the second, the effect of adding the solutions to a given soil was ascertained.

The procedure in the first series was as follows: Fifty uniform seeds were chosen and were steeped for twenty-four hours in 200 cubic centimeters of pure solutions of each substance to be studied. Following this treatment the seeds were removed, carefully rinsed in distilled water, and placed between filter papers over moistened sphagnum. When the roots of the control seed — those steeped in distilled water for twenty-four hours — had grown to about two inches in length final notes were taken.

The conditions for germination were identical, inasmuch as the treated seeds and the controls were placed in the same germinating pan. Ordinary room temperatures were maintained. The results obtained are summarized in the following table:

TABLE 9. The Effect of Certain Salts on Germination

Experiment with $CaCl_2$		
Steeped for twenty-four hours in following solution	Percentage of germination	Notes on condition of roots
Distilled water	96 to 98	Uniform germination. Roots 6.25 centimeters in length
N/1 $CaCl_2$	10	Roots about .6 centimeter in length, enlarged, tips dead
N/3 $CaCl_2$	95	Roots about 1.25 centimeter in length
N/5 $CaCl_2$	96	No injury

TABLE 9—(*continued*)

Experiment with $MgCl_2$

Steeped for twenty-four hours in following solution	Percentage of germination	Notes on condition of roots
Distilled water	96 to 98	Uniform germination. Roots 6.25 centimeters in length
N/1 $MgCl_2$	8	Roots .3 centimeter long, dead
N/3 $MgCl_2$	95	Great injury. Roots .3 to .6 centimeter long, curled
N/5 $MgCl_2$	96	Great injury. Roots 1.22 centimeter long, curled
N/10 $MgCl_2$	96	Slight injury. Roots 5 centimeters in length

Experiment with KCl

Steeped for twenty-four hours in following solution	Percentage of germination	Notes on condition of roots
Distilled water	96 to 98	Uniform germination. Roots 6.25 centimeters in length
N/1 KCl	5	Dead
N/3 KCl	96	Three roots are normal, remainder show great injury, 1.25 centimeter long
N/5 KCl	96	Great injury. Roots about 1.25 centimeter long
N/10 KCl	97	No injury

Experiment with NaCl

Steeped for twenty-four hours in following solution	Percentage of germination	Notes on condition of roots
Distilled water	96 to 98	Uniform germination. Roots 6.25 centimeters in length
N/1 NaCl	0	
N/3 NaCl	90	Great injury. Roots about .6 centimeter long
N/5 NaCl	95	Great injury. Roots about 1.25 centimeter long
N/10 NaCl	96	No appreciable injury

TABLE 9—(*concluded*)

Experiment with NH_4Cl

Steeped for twenty-four hours in following solution	Percentage of germination	Notes on condition of roots
Distilled water	96 to 98	Germination uniform. Roots 6.25 centimeters long
N/1 NH_4Cl	0	
N/3 NH_4Cl	0	
N/5 NH_4Cl	30	Roots about 1.25 centimeter long
N/10 NH_4Cl	75	Roots show great injury
N/20 NH_4Cl	80	Roots show slight injury

Experiment with $MnCl_2$

Steeped for twenty-four hours in following solution	Percentage of germination	Notes on condition of roots
Distilled water	96 to 98	Germination uniform. Roots 6.25 centimeters long
N/1 $MnCl_2$	6	Roots dead, barely emerged
N/3 $MnCl_2$	94	Great injury. Roots .6 to 1.25 centimeter long
N/5 $MnCl_2$	96	Great injury. Roots 1.25 centimeter long
N/10 $MnCl_2$	97	Two roots are about normal, remainder show great injury
N/50 $MnCl_2$	98	Twenty-five roots are about normal, remainder show injury

The ions of magnesium, sodium, potassium, and calcium are injurious in the order given, magnesium being only slightly more harmful than either sodium or potassium. Of the salts tested, NH_4Cl alone inhibits germination at N/3 concentration.

In general these results are similar to those obtained by Magowan (1908), who germinated wheat seeds in pure solutions of certain salts and allowed them to remain in the solutions for thirty days. It was found that magnesium chlorid, sodium chlorid, potassium chlorid, and

calcium chlorid are toxic in the order given. The results obtained by Magowan are presented in the following table:

	.02 m	.04 m	.06 m	.08 m	.12 m	.18 m
$MgCl_2$	64mm	26mm	15mm	10mm	6mm	0mm
NaCl	446	321	210	134	54	24
KCl	462	333	220	144	63	31
$CaCl_2$	552	386	249	168	84	48

Ammonium and manganese ions are far more deleterious than the above. Seeds steeped in N/20 NH_4Cl show slight injury, while those steeped in N/50 $MnCl_2$ are greatly injured. Whether these variations are due to the difference in penetrability of the seed covering, the writer is unable to judge from the data that he has obtained.

The procedure in the second series of experiments was as follows: Two hundred and fifty grams of air-dry soil (volatile matter 3.45 per cent) was placed in glass tumblers. Ten uniform pea seeds were placed in each tumbler, about one inch below the surface of the soil. One hundred and twenty-five cubic centimeters of the solutions to be studied was added to each tumbler of soil. The chlorids of ammonium, magnesium, potassium, and calcium are injurious in the order given. These results suggest that fertilizers should be judiciously applied to soils.

TABLE 10. GERMINATION OF SEED IN SOIL AS AFFECTED BY SALTS

Experiment with $CaCl_2$

Composition of solution	Length of tops (centimeters)	Length of roots (centimeters)	Notes on condition of roots
Control	7.50	8.9 branched	
N/1 $CaCl_2$	0	0	
N/3 $CaCl_2$	0.60	1.25	Dead. Few lateral roots
N/5 $CaCl_2$	1.25	3.75	Dead. Few lateral roots
N/10 $CaCl_2$	7.50	7.00	No injury

TABLE 10—(*concluded*)

Experiment with $MgCl_2$

Composition of solution	Length of tops (centimeters)	Length of roots (centimeters)	Notes on condition of roots
N/3 $MgCl_2$	0	0	
N/5 $MgCl_2$	Slight	Slight	Lateral roots very short
N/10 $MgCl_2$	1.25	5.00	Few short lateral branches
N/20 $MgCl_2$	2.50	8.75	No injury

Experiment with KCl

Composition of solution	Length of tops (centimeters)	Length of roots (centimeters)	Notes on condition of roots
N/1 KCl	0	0	
N/3 KCl	0	0	
N/5 KCl	1.25	2.50	Great injury
N/10 KCl	1.25	5.00	Slight injury

Experiment with NH_4Cl

Composition of solution	Length of tops (centimeters)	Length of roots (centimeters)	Notes on condition of roots
N/3 NH_4Cl	0	0	
N/5 NH_4Cl	0	0	
N/10 NH_4Cl	1.85	5.00	Slight injury
N/20 NH_4Cl	2.50	5.25	No injury

CONCLUSIONS

Barium, strontium, ammonium, magnesium, sodium, and potassium, in the order given, when present in pure solution are very toxic to seedlings. This toxicity is greatly reduced by either full nutrient solutions or soil cultures.

Under the conditions of the experiments much stronger solutions are required in order to prevent top growth than to kill the roots of seedlings.

Seedlings that have been grown for ten days in either distilled water, tap water, or full nutrient solutions are far more resistant to any toxicant studied than are those that are placed immediately in the toxic solutions.

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ACKNOWLEDGMENT

These investigations were suggested by Professor B. M. Duggar. For this and many valuable suggestions concerning details of manipulation, and for aid in preparation of the manuscript, the writer acknowledges his indebtedness. The writer desires also to thank Professor Lewis Knudson for helpful advice.

OCTOBER, 1912 CIRCULAR No. 13

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Dairy Industry

PROPAGATION OF STARTER FOR BUTTER MAKING AND CHEESE MAKING

E. S. GUTHRIE AND W. W. FISK

(Revision of Circular 10)

A starter is a material containing desirable bacteria for the ripening, or souring, of dairy products. These bacteria may be purchased of companies whose advertisements appear in the dairy journals. The growing

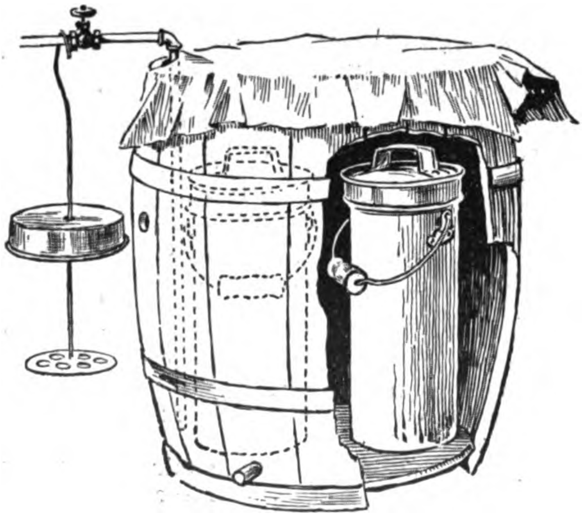

FIG. 1.—*Barrel and shotgun can and agitator*

of the bacteria in whole milk or in skimmed milk is known as starter making.

The method presented may sometimes be varied and still good results be secured, but a beginner should not experiment until he fully understands the principles involved in the propagation of starter.

APPARATUS

In the cultivation of starter the usual practice is to carry the starter from day to day in a small quantity, which is more carefully handled than the major part. This small amount of starter is termed "mother starter." The choice of containers for mother starter depends largely on conditions and on the preference of the operator. Glass is somewhat preferable, for through it dirt is easily detected and the condition of the curd is readily noted. Two or three bottles should be used, for in pasteurization they may break. Metal holders, as copper properly tinned, or heavy tin, may be used. It is always well to use a sufficient number of containers so that careful selection is possible.

Usually it is necessary to propagate the mother starter two or three times before the flavor of the commercial culture, which is often very disagreeable, will disappear.

STEPS IN PROPAGATION OF MOTHER STARTER

1. Take three one-quart bottles or fruit jars.[1]

2. Use fresh, clean milk, which must have a good flavor. It may be either whole milk or skimmed milk. Usually it is advisable to use whole milk, for it is easier to choose desirable samples before milk has passed through the separator than afterward.

3. Fill the containers one half to two thirds full of milk. If they are filled full it is difficult to prevent contamination from the covers, which are hard to sterilize when the pasteurization is done in hot water.

4. Protect the containers with regular covers (caps or tops).

5. Pasteurize by heating to a temperature of 180 to 200° F. for thirty minutes or longer, and then cool to ripening temperature of 60 to 75° F. Pasteurization may be accomplished by tying a string about the necks of the bottles and suspending them in a pail or vat heated by steam or in a kettle or dish heated on a stove. (If pasteurized over a fire, do not let the bottles rest on the bottom of the receptacle.) Other supports may be used to keep the containers from tipping over. If glass containers are used, the temperature should be raised and reduced slowly in order to prevent breaking.

6. After pasteurization the milk is ready for inoculation. Inoculate in a quiet place where the wind cannot blow dirt and bacteria into this clean seed bed. With dry fingers remove the cover and place it in a clean spot. Pour in all of the commercial culture, or two to ten per cent from the previous day's culture.[2]

7. Ripen at about 60 to 75° F. The first inoculation from the commercial culture should be ripened at about 70 to 85° F. The smaller inoculations require higher temperatures than do the larger inoculations. By experience an operator can soon learn what inoculation and temperature should be used to ripen his starter in a given time. Usually a 1 to

[1] Larger receptacles may be used if desired.

[2] The amount of ripened starter for inoculation can be measured accurately in a vessel, such as a sterilized cup or spoon, or it can be determined rather closely by the eye. Place the thumb above the milk line in the bottle to be inoculated, in this way measuring the amount to add, and raise the milk line to that mark by pouring in the ripened starter. Be sure that the curd from the previous day is well broken. After inoculation, shake the freshly inoculated sample so as to distribute the bacteria.

8 per cent inoculation will ripen a starter in twelve hours at about 65° F. The temperature must be fairly constant.

8. The starter is ripe when a curd forms. This curd should be soft and like custard in appearance; it should not be hard and firm.

9. When the starter is ripe it should be used at once. If this cannot be done, cool to 50° F. or lower. Do not shake the starter before putting it in storage.

10. On examination the curd should be smooth and compact, without gas pockets. Gas shows the presence of undesirable bacteria. A hard, lumpy curd, whey, and high acid show overripeness, which is very undesirable. After the state of the curd is noted, shake well to break it into a smooth, lumpless condition. Shake with a rotary motion, being careful not to touch the cap for fear of contamination. Now smell and taste it, but never from the starter container; always pour some of the curd into a spoon or cup and then replace the cover immediately. After smelling, it is best to put at least a teaspoonful into the mouth. Seek for a desirable, clean, mild, acid flavor. The first propagation is likely to be somewhat disagreeable because of the presence of some of the original medium.

DIRECTIONS FOR USE IN A CREAMERY

In a creamery or a large dairy it is necessary to carry more than a pint or a quart of starter. Along with the mother starter a second starter of ten to fifty pounds may be carried. After the mother starter in the glass container is inoculated, the remainder of the previous day's mother starter is poured into the second starter, and the cream is inoculated from the second starter. In large creameries, third and fourth starters are carried.

The improved starter can is a labor saver, but not an absolute necessity. It may be used to advantage when circumstances warrant it. Some starter makers prefer to use shotgun cans; others like the regular ten-gallon milk cans. In either of the two last-named cases the temperatures can be easily controlled for pasteurization and ripening by placing the cans in a barrel or in a plank box. During pasteurization it is necessary to agitate the milk. In this larger quantity the pasteurization temperature need not be above 180° F. for twenty or thirty minutes. Care should be exercised not to give the milk a pronounced cooked flavor; otherwise this larger quantity of starter should be handled in the same manner as is the mother starter.

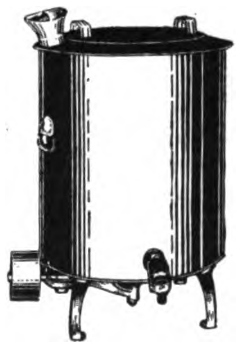

FIG. 2.—*Improved starter can*

It is necessary to use a larger inoculation from starter to cream than from starter to starter, because the seed bed is not so well prepared. The inoculation of the cream may vary from 8 to 50 per cent.

A starter may be carried two to four weeks before it goes "off." Often it is carried several months, and often less than two weeks. This depends almost altogether on the carefulness of the operator.

DIRECTIONS FOR USE ON A FARM

On a farm the cream might be handled in the following manner: Suppose the dairyman separates, each half day, ten pounds of cream testing about thirty-five per cent butter fat. On Monday a new starter of about two thirds of a quart is inoculated from a starter that has been held from Friday or Saturday. The remainder of the held-over starter is put in the ten pounds of cream. The cream is then set at about 65° F.; it may have to be set in a cooler place before evening. In the evening ten pounds more cream are added, and all the cream, which is now in the one vessel, is set at about 60° F. On Tuesday morning add the morning's cream and set at 60 to 65° F., as during the day it is more convenient to watch the ripening process than at night. In the evening add the evening's cream and set at 58 to 60° F., for by this time there is a very large army of bacteria at work. On Wednesday morning churn the forty pounds of cream and start the ripening process anew with Wednesday's cream.

It is important not to develop too much acid. The amount of inoculation and the temperature must be managed so as to gain a certain end under certain conditions.

DIRECTIONS FOR USE IN A CHEESE FACTORY

Starter is used in cheese making for two purposes: first, to improve the flavor of the resulting cheese; and second, to hasten the development of lactic acid. There is a tendency on the part of the cheesemaker to use too much starter, thus hurrying the cheese-making processes; this reduces the yield of cheese and is likely to cause an acidity cheese.

The starter should be strained into the vat of milk so that there will be no lumps, since lumps cause uneven color and texture. All the starter should be added before the color is put in.

In general, from .5 to 2 per cent of good commercial starter can be safely used. If the milk is overripe, a small percentage can be added just before the rennet is added. This will not hurry the process, but will improve the flavor. If the milk is gassy or if it is thought that the starter will work slowly, a larger percentage may be used. This can be put into the milk and left some time before the rennet is added, so that it will become rather active. In no case should so much starter be used that the curd does not have time to contract naturally before the whey is removed.

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Poultry Husbandry

WORKING PLANS OF CORNELL POULTRY HOUSES

C. A. ROGERS

This circular contains working plans and a brief explanation of several types of approved poultry houses and appliances. Very similar designs have been shown in Reading-Course Lesson No. 33, Circular No. 1 of the Department of Poultry Husbandry, and Bulletin 274 of the Cornell

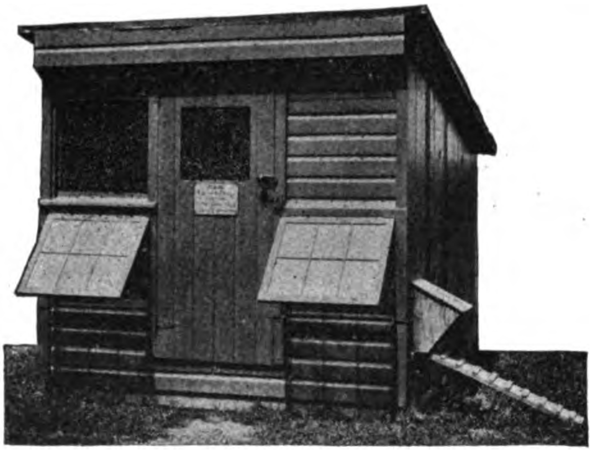

FIG. 3.— *The Cornell breed-testing house. The door and windows are cased over the siding. The exit door is boxed in so as to prevent drafts*

University Agricultural Experiment Station. All these publications are now out of print.

The poultry houses described herein do not represent any one person's original ideas. They are the result of a compilation of the suggestions and ideas of several members of this department, emanating from a study of other types and styles of houses recommended and in use in other parts of the country. Opinions on poultry-house construction are constantly changing as experience shows the wisdom of placing greater emphasis on different principles of construction.

THE CORNELL BREED-TESTING HOUSE

The building shown in Figs. 3, 4, 5, and 6 is a colony house eight feet square, which is used in the Cornell breed-testing work. It will hold ten to fifteen fowls. This type of house is suitable for a small flock of breeding fowls or for young chickens on the farm, and is especially desirable for a small flock in the village or town.

A cross-section view of this building is shown in Fig. 4. There are two 2x2-inch perches 3 feet 6 inches long. These perches are boxed in, so

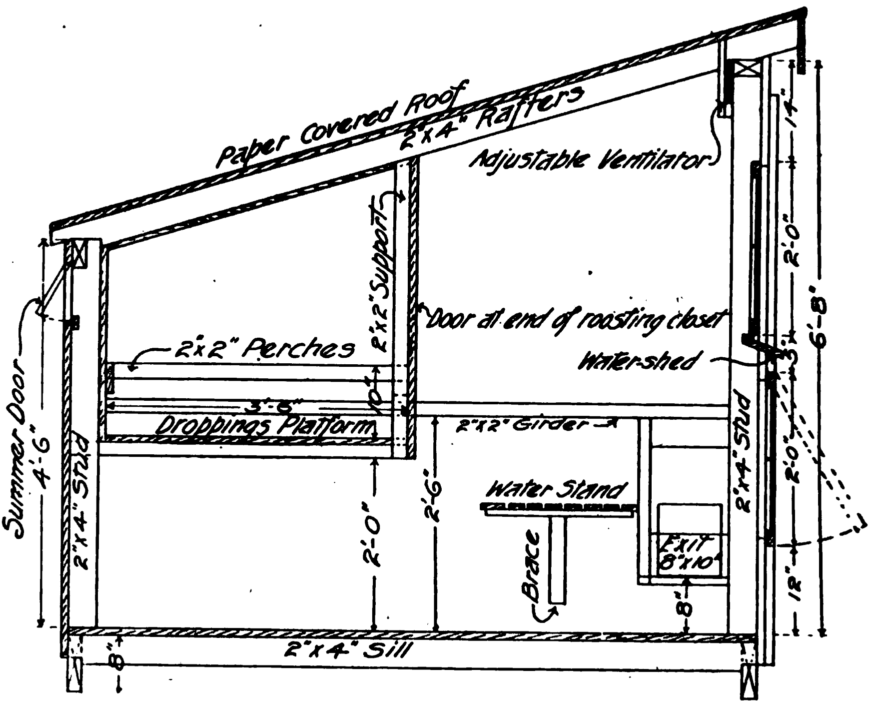

FIG. 4.—*A cross-section plan of the Cornell breed-testing house. Note the construction of the windows, water-shed, and ventilating doors in the back and front walls*

to speak, on all sides except the front. The rear 2x4-inch plate is placed on edge so as to allow a circulation of air around the roosting closet. The front end of the closet is hinged to swing back against the side wall in summer.

The water stand is made of slats in order to allow the filth to fall to the floor. All the fixtures are raised above the floor so as to give greater floor space, to make cleaning easier, and to elevate the water pan and other appliances above the litter, which is disturbed when the fowls are at work on the floor.

This house is ventilated, during the winter, through a cloth curtain in the door, shown in Fig. 5. During the summer, greater circulation of air can be obtained by opening the windows in front and the small door behind the perches, and by dropping the adjustable board ventilator in the peak.

Heavier timbers can be used underneath, if desired, to serve as runners

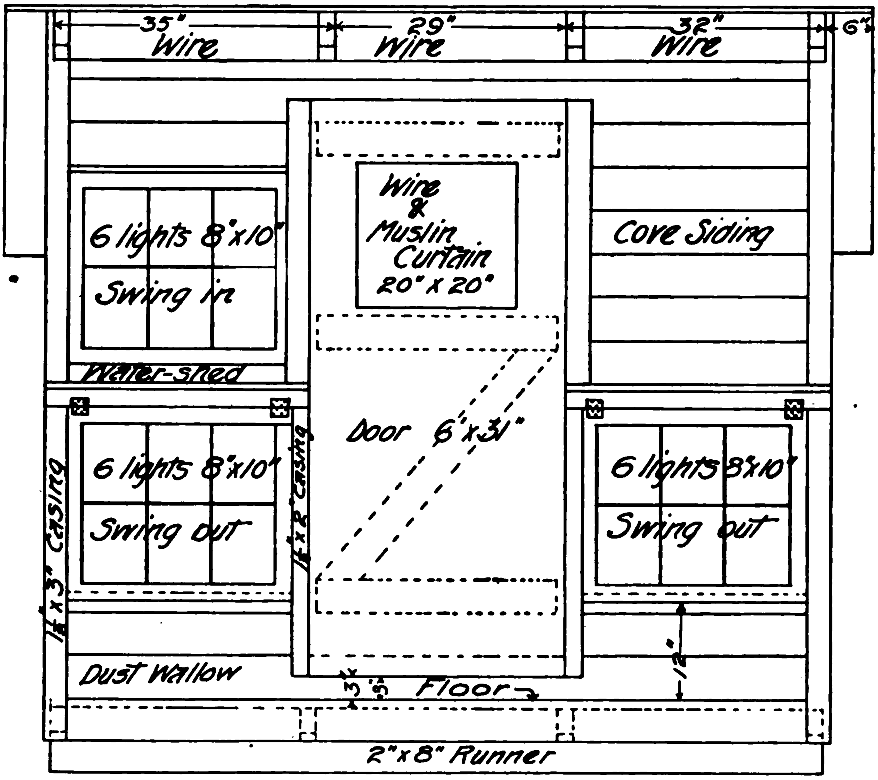

FIG. 5.— *Front elevation of the Cornell breed-testing house. Note the size and location of ventilators in door and in peak between rafters. The rafters are spaced unevenly in order to assist in the interior construction*

on which to draw the house from place to place. A double floor, also, would make the building stronger, tighter, and warmer.

The two lower windows are placed outside the siding and cased in with lumber of their own thickness. The opening in the siding, over which the window fits, is three fourths of an inch smaller on each side. This projection serves as a stop and makes a tighter construction. The upper window fits between two upright timbers and swings in from the side. The siding and casing are extended three fourths of an inch inside the edge

of the window sash, to serve as a stop and a wind cover. Between the upper and lower windows there is a water-shed with a small baseboard fastened to it on the upper side. This baseboard is similar to the construction shown in Fig. 28. The wire mesh covering the windows is fastened to the outside of the studding before either siding or casing is placed.

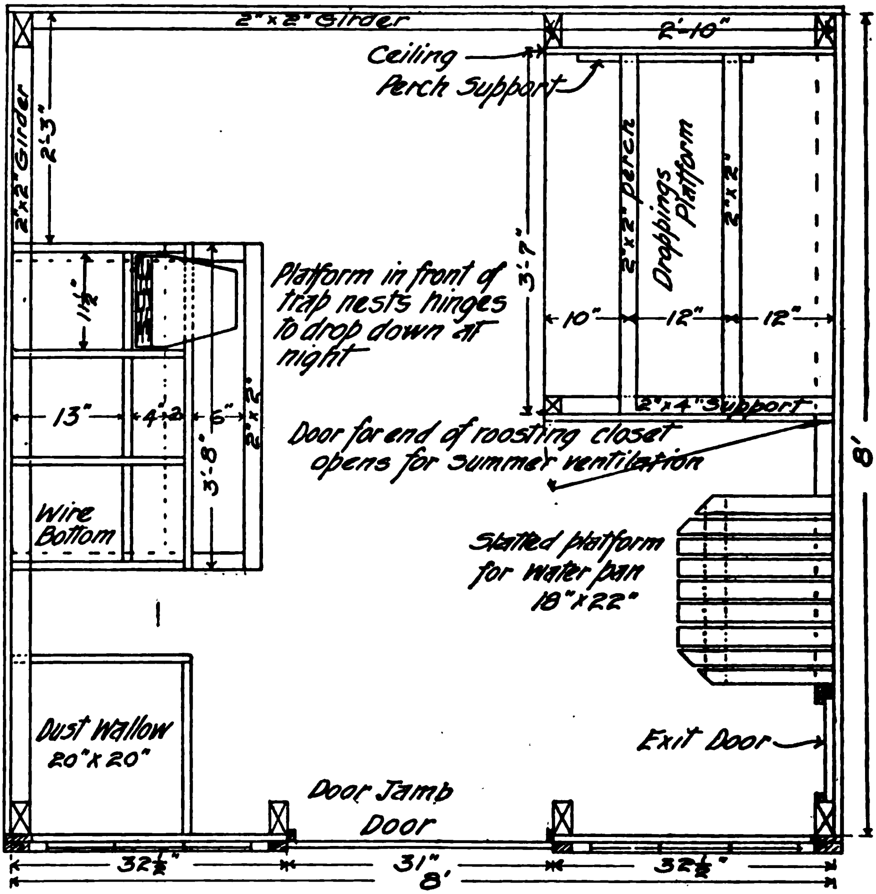

FIG. 6.— *Floor plan of the Cornell breed-testing house, showing the location of different fixtures and timbers*

The casings for the door, windows, and sides are placed over the siding.

The detail of the trap nest and broody coop used in the breed-testing house is shown in Fig. 7. The nest boxes rest on a 2x2-inch platform and are hooked to the rear wall. The top of the nest serves as a platform to catch the droppings from the broody coop. The platform is loose so that it can be drawn out for cleaning. The bottom of the broody coop

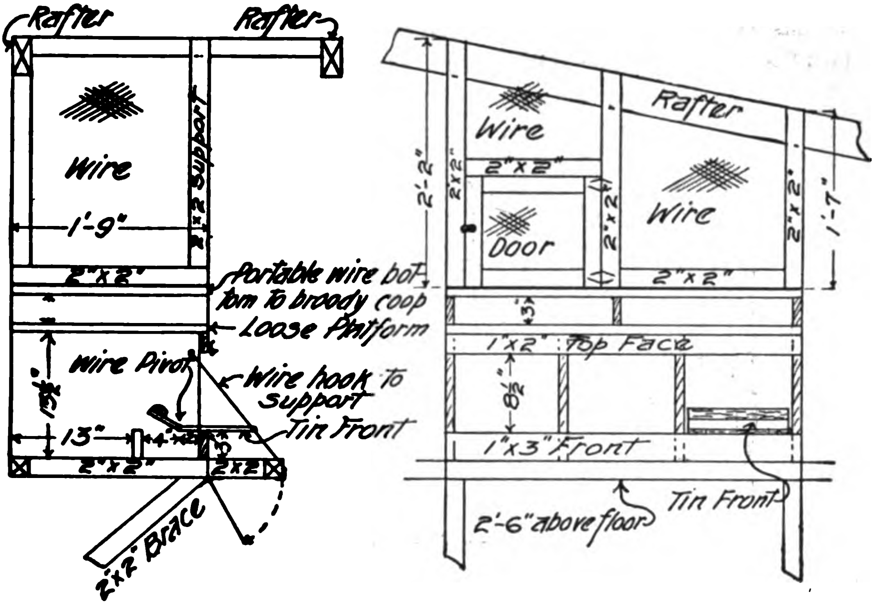

FIG. 7.— *A cross-section and front elevation of the trap nest and broody coop used in the Cornell breed-testing house. There are three nests below and a broody coop above*

FIG. 8.— *The Cornell poultry house with pens 12 feet square. There is a door in the partition between pens. The cloth curtain is made of loosely woven unbleached muslin*

consists of a frame covered with half-inch galvanized hardware cloth. This floor is fastened to three boards that rest on the droppings platform.

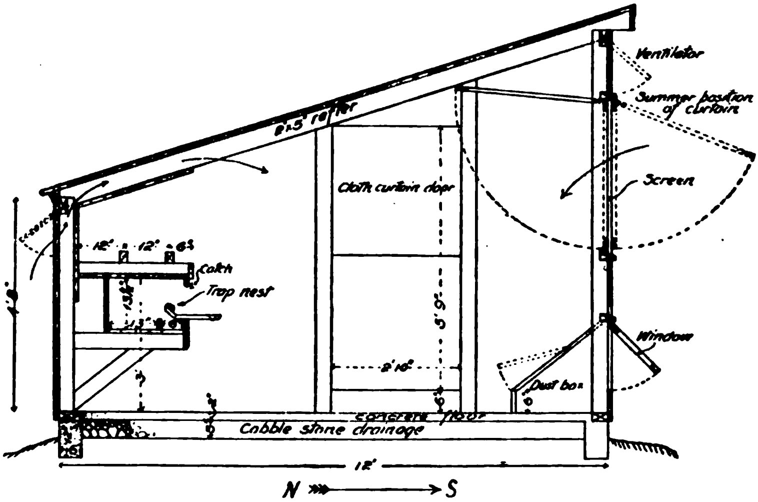

Fig. 9.— *A cross-section plan of the Cornell poultry house with pens 12 feet square. Note the ceiling around the perches*

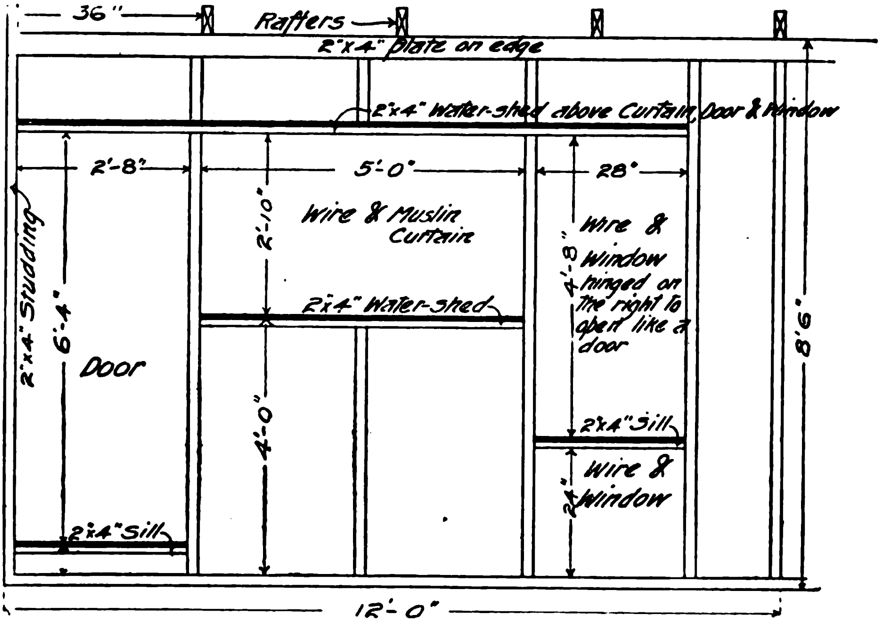

Fig. 10.— *Front elevation of the Cornell poultry house with pens 12 feet square, showing the frame construction*

It also is portable. The 2x2-inch supports and framework to which the wire for the broody coop is fastened are nailed to the rafters and side wall.

THE CORNELL POULTRY HOUSE WITH PENS TWELVE FEET SQUARE

A corner view of the Cornell poultry house with pens 12 feet square is shown in Fig. 8 and working plans of it are shown in Figs. 9, 10, and 11.

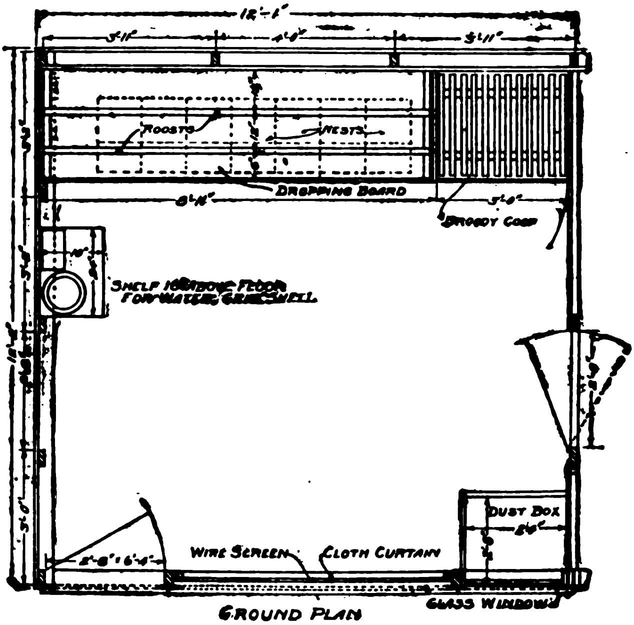

FIG. 11.— *Floor plan of the Cornell poultry house with pens 12 feet square, showing size and location of the interior fixtures and timbers*

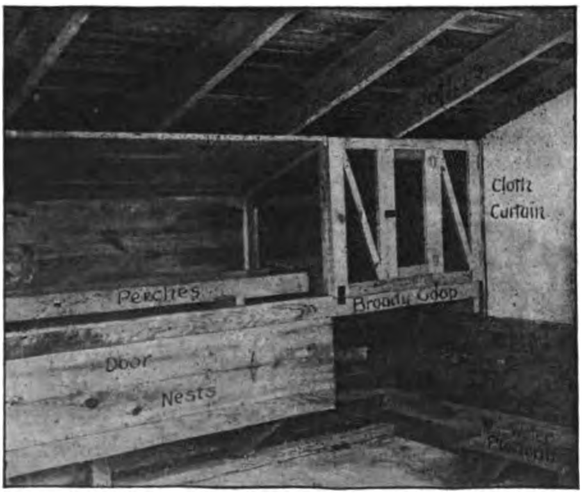

FIG. 12.— *The broody coop, nests, and roosting fixtures in the Cornell poultry house with pens 12 feet square*

This house is recommended for farm flocks of fifty to seventy fowls. For such a flock it should have two pens, as shown in Fig. 8. This makes it possible to keep the old fowls separated from the pullets, or, better still, to keep the best fowls for breeding in one pen, separated from the others.

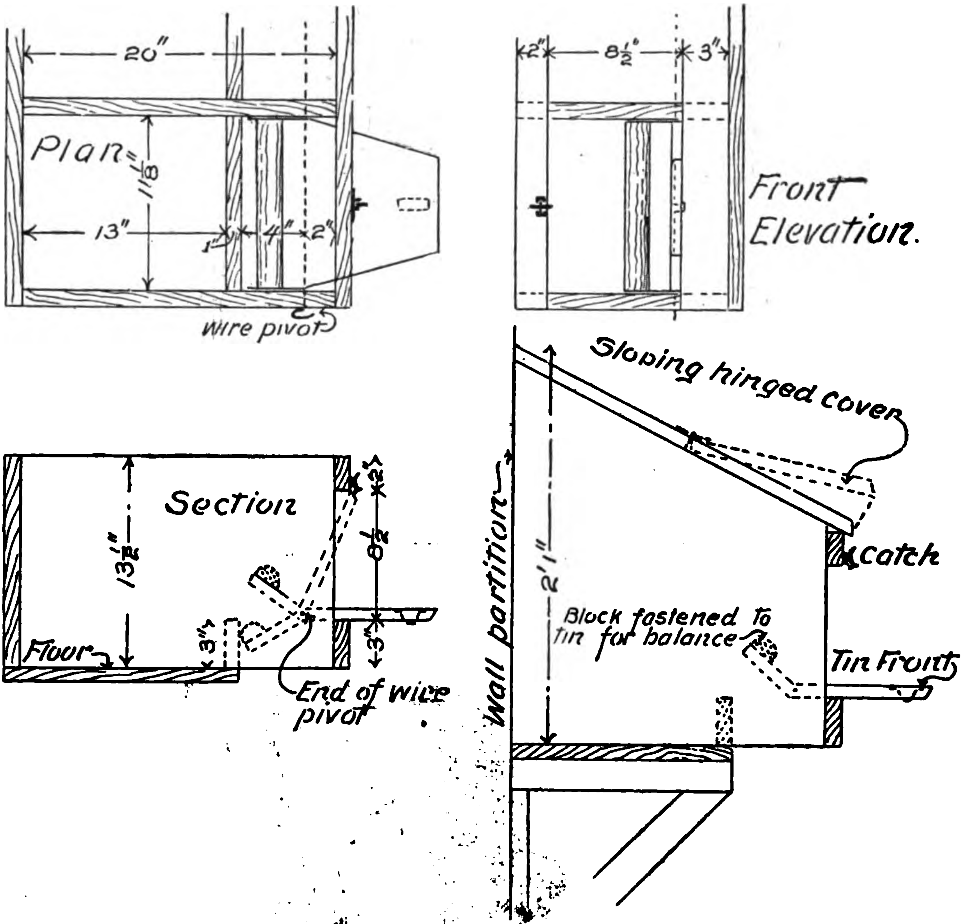

FIG. 13.— *The improved Cornell trap nest. This illustration pictures a nest with the medium-sized tin front. The fronts can be made by any tinsmith. Care should be taken to use a balance block heavy enough to close the trap when partly lifted*

The size of the muslin curtain should be varied in different parts of the State. The size of the curtain shown in Fig. 8, 3 feet 4 inches by 6 feet 4 inches, is recommended for the warmer sections. In the extremely cold counties a curtain only 4 feet long and 2½ or 3 feet high would be more satisfactory. The front elevation plan, illustrated in Fig. 10, shows a

curtain 5 feet long and 2 feet 10 inches high. This is suitable for medium temperatures.

The foundation and floor of this house are of concrete. A wall 6 inches

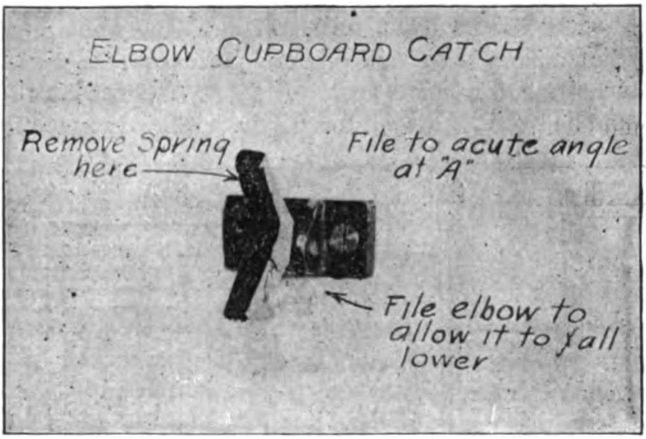

FIG. 14.— *The single catch that locks the tin front of the trap nest*

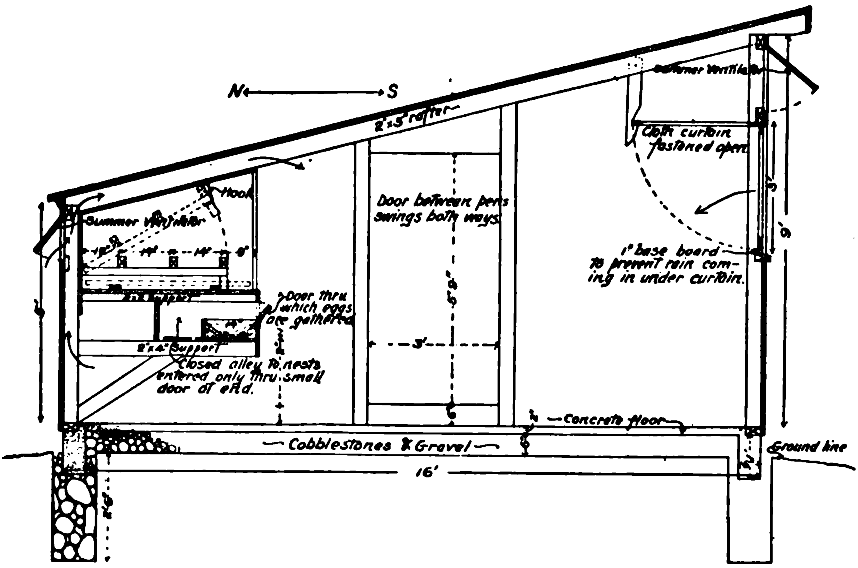

FIG. 15.— *A cross-section plan of the Cornell poultry house with pens 16 feet square. The summer ventilator extends the entire length of the pen*

thick and 12 inches high (7 inches above the ground) is built above a trench filled with cobblestones. The trench should be about 1 foot deep, except in a very cold climate and on a heavy soil, in which case it should

be deeper. The concrete floor is 2 inches thick and consists of rough concrete, only. This is made of one part of cement and six parts of medium gravel; or one part of cement, two parts of sand, and four parts of screened gravel or stone. These are mixed together until the mass shows a uniform color, then water is added and mixed in until the whole is thoroughly wet. This mixture is then tamped into place and the surface floated level and smooth with a board float. If a smoother finish is desired, the surface should be troweled after it has partly dried and started to set. The

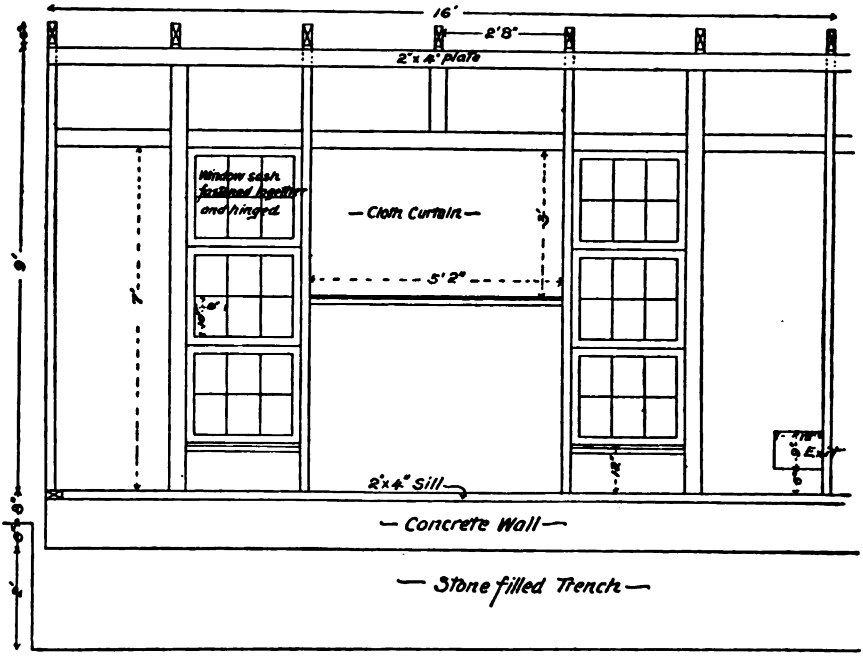

FIG. 16.— *Front elevation of the Cornell poultry house with pens 16 feet square. The window sashes are fastened together and hinged on the side so as to open like a door. Windows not to be used as doors are covered with poultry-wire netting*

concrete rests on 5 inches of cobblestones and gravel, or hard cinders (not coal ashes). This coarse material separates the concrete from the moist earth and keeps the moisture from coming up through the concrete.

In many cases, where the stone and gravel filling is very shallow, or where the ground is very heavy and damp, it is well to insure dryness by using tar paper beneath the concrete or by adding air-slaked lime. When using tar paper, level, dampen, and pound down the gravel filling. Sweep a light coat of clear sand over the gravel so as to protect the paper from being cut by the coarser parts of the gravel, and lay over this smooth surface one thickness of one-ply tar paper with edges overlapping one

half the width of the paper; or, better still, use three layers of one-ply tar paper with a coat of tar paint between the layers. Over the tar paper spread the 2-inch layer of rough concrete, as described above. In addition to preventing the upward passage of water, the tar paper prevents the downward passage of heat, thereby providing a warmer floor.

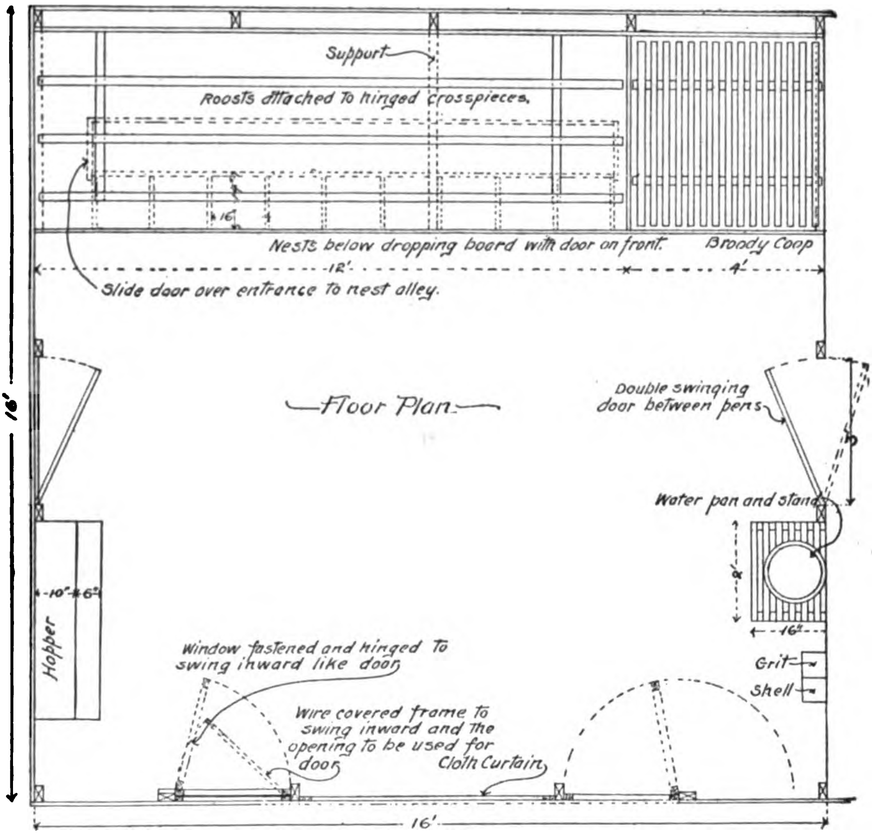

FIG. 17.— *Floor plan and interior arrangement of the Cornell poultry house with pens 16 feet square*

When moisture-proofing the concrete with lime, add an equal part of air-slaked lime to the cement and mix thoroughly before adding to the sand and gravel. This latter method, however, does not give so strong and satisfactory a floor as does the former.

The house is ventilated in winter by the cloth curtain, and in summer by a small door at the top of the front side, by opening the glass window, and by the small door at the top of the back side. The muslin curtain is hinged on the outside and fastened up to serve as an awning during the hot summer months.

The roosting closet is enclosed in the same way as in the breed-testing house.

. The partition between pens should be made of wood alone, or of wood and cloth. The cloth should not be used where there is likelihood of striking and tearing it while cleaning the pens.

The nests are located beneath the droppings platform, and rest on a table attached to the rear wall. The nests shown in Fig. 9 are for traps. A nest similar to those shown in Figs. 15 and 21 can be used if preferred.

The dust box used in this house is enclosed on all sides. The hens enter it through a small opening in the side. The covered wallow prevents a great deal of dust from getting into the open pen, although the fowls will often leave the box before shaking themselves.

The broody coop is located at one end of the perches. It is shown here (Figs. 11 and 12) with slatted bottom and wire sides, extending from the droppings platform to the ceiling. A perspective view of this coop is shown in Fig. 12.

THE CORNELL POULTRY HOUSE WITH PENS SIXTEEN FEET SQUARE

The working plans of the house with pens 16 feet square, shown in Figs. 15, 16, and 17, illustrate a type of house very similar to the house with pens 12 feet square. The 16-foot house is somewhat larger, holding about seventy-five hens in each pen. It can be built more economically than the 12-foot house, considering its capacity.

There are two windows in the front of each pen. Each window is made of three six-light sashes, 8x10-inch glass, fastened together with strips of iron or wood. The windows are hinged on one side so as to swing open against the side wall, and to use when cleaning if the house contains several pens.

The doors used daily are in the end and partition walls of the house.

In Fig. 15 is shown, beneath the foundation wall, a trench much deeper than it is ordinarily necessary to make.

The nests in this house are located underneath the droppings platform. Behind the nests there is an enclosed passageway that is entered at either end. Slide doors can be used at these ends to be closed at night and thus prevent the hens from returning. The eggs are gathered through a door in the front. A more detailed plan of the nest, as it is adapted to side-wall use, is shown in Fig. 28.

THE CORNELL POULTRY HOUSE WITH PENS TWENTY FEET SQUARE

Although it is commonly believed that hens give greater production when kept in small flocks, there is abundant evidence of the satisfactory production of fowls in flocks of one hundred to five hundred hens.

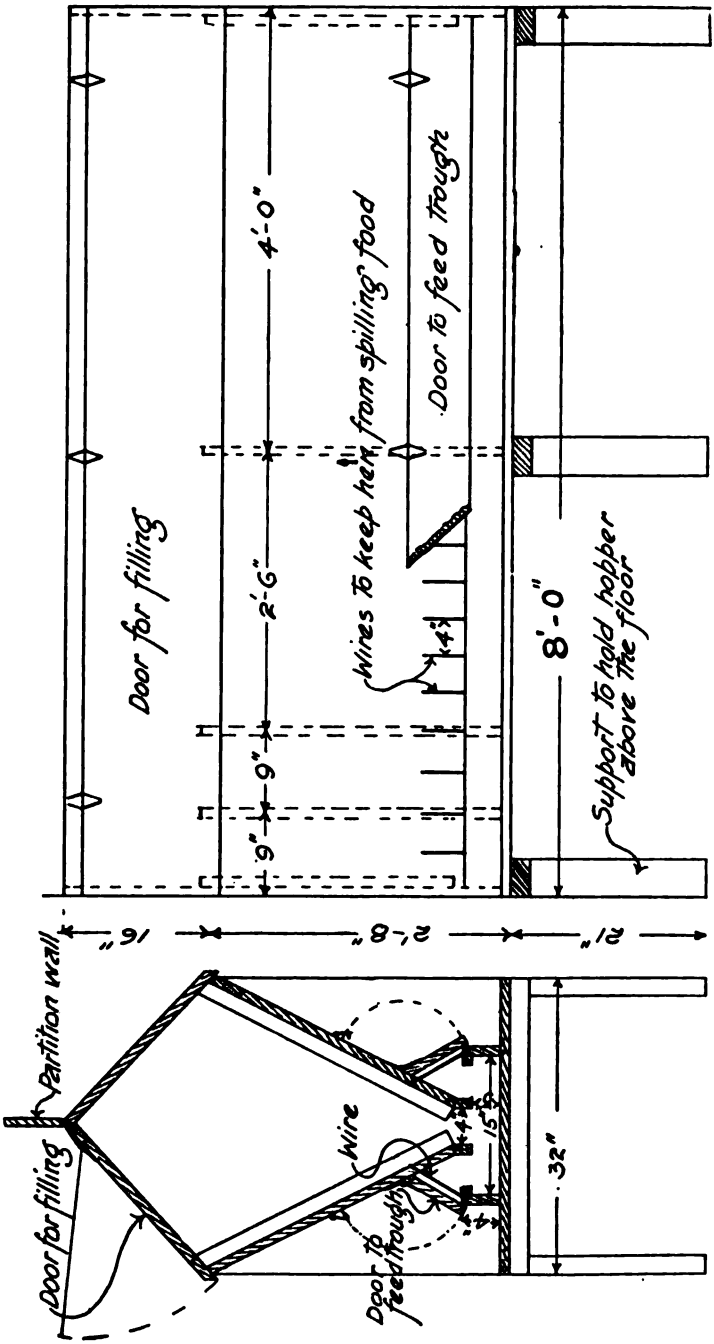

FIG. 18.—*A detailed plan of the Cornell double feed hopper used in the partition wall between two 20-foot pens in a long house. The partitions in this hopper can be adjusted to suit the needs of the feeder. More small compartments can be added. For smaller pens the hopper can be shortened*

On farms where a large number of fowls are kept it is economical to use pens of relatively large size and keep more individuals in each flock,

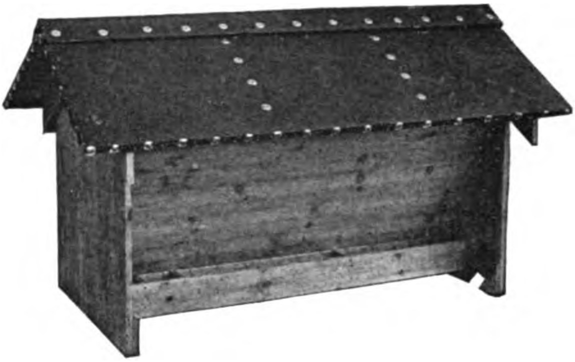

FIG. 19.—*A Cornell feed hopper similar to the one shown in Fig. 18, adapted to outdoor use. There are no doors over the feed trough. There is no platform and the trough is elevated only 2 inches above the ground. The top projects over the side for protection*

rather than to have a greater number of smaller buildings. There is, of course, a point of maximum profit between the saving of labor in the man-

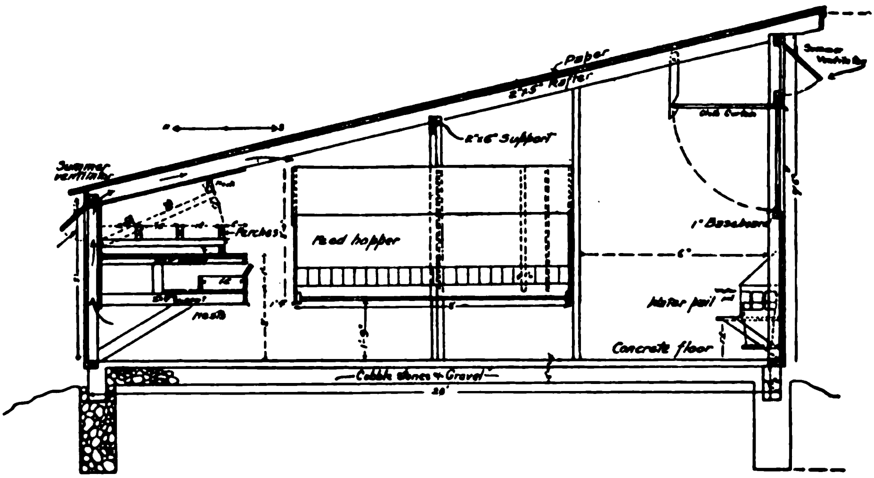

FIG. 20.—*A cross-section plan of a Cornell poultry house with pens 20 feet square. Note that all fixtures are above the floor. Two 12-foot rafters instead of one 21-foot rafter can be used, in which case the ends of the 12-foot rafters would side-lap each other over the center support*

agement of large flocks and the greater individual production of small flocks. This point of greatest efficiency, it is believed, lies in flocks rang-

ing from one hundred to five hundred fowls each, housed in pens twenty or more feet deep. A pen 20 feet square will provide sufficient space

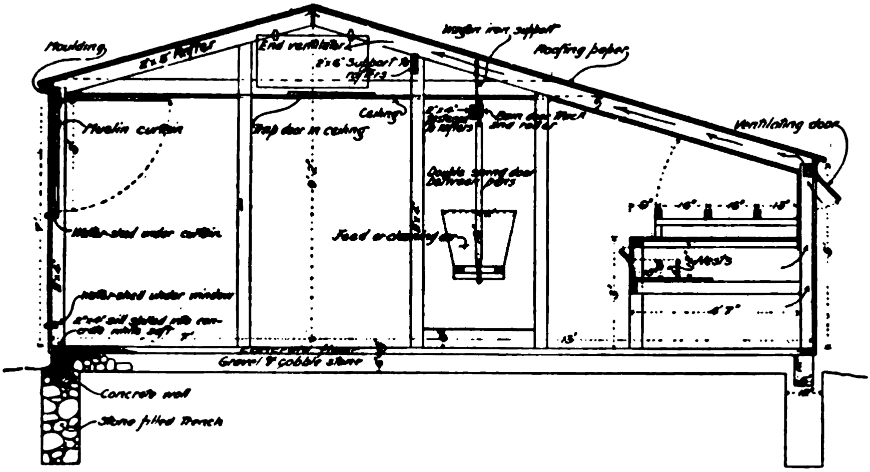

FIG. 21.—*A cross-section plan of a Cornell poultry house with pens 20 feet square, adapted to the combination roof type of construction and interior ceiling*

for one hundred to one hundred and twenty-five fowls. In Figs. 20 to 26 are shown working plans of various types of houses with pens 20 feet square.

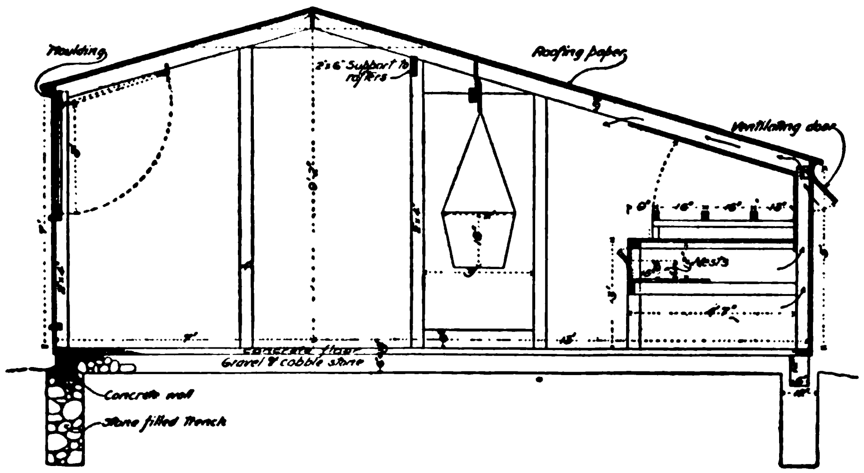

FIG. 22.—*A cross-section plan of a Cornell poultry house with pens 20 feet square, adapted to the combination roof and ceiling around perches only*

There are several types of 20-foot houses illustrated in this circular. The cross-section plan of a Cornell poultry house with pens 20 feet square

is illustrated in Fig. 20. In Fig. 21 is shown the cross-section plan of this house adapted to a combination roof with an inside ceiling of matched

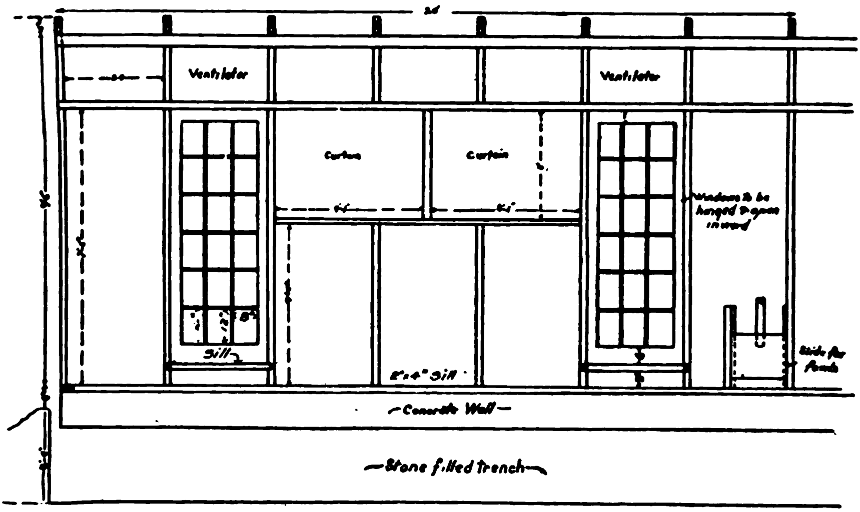

FIG. 23.— *Front elevation of a Cornell poultry house with pens 20 feet square. This has two cloth curtains, making it possible to open one or both at the same time. The windows shown here are of a special size made to order. Sashes similar to those shown in Fig. 24 can be substituted*

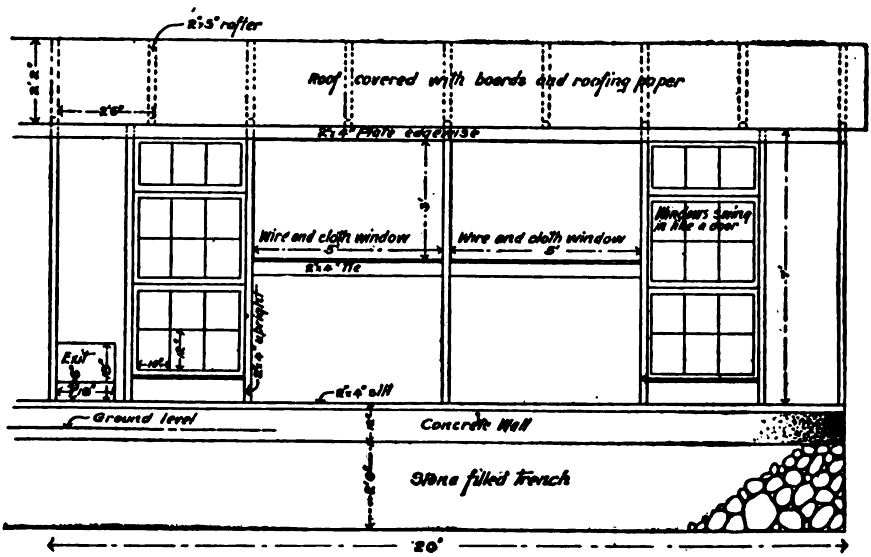

FIG. 24.— *Front elevation of a Cornell poultry house with pens 20 feet square, adapted to the combination roof*

lumber. In Fig. 22 is shown the end plan of a similar house without the ceiling. The interior arrangement and equipment of these pens is the

same for all practical purposes. The ceiling in the house illustrated in Fig. 21 makes the pen warmer in winter and cooler in summer. Where the temperature becomes very severe at times, a ceiling of tight boards, or of loose boards or wire covered with straw, is desirable. The ceiling,

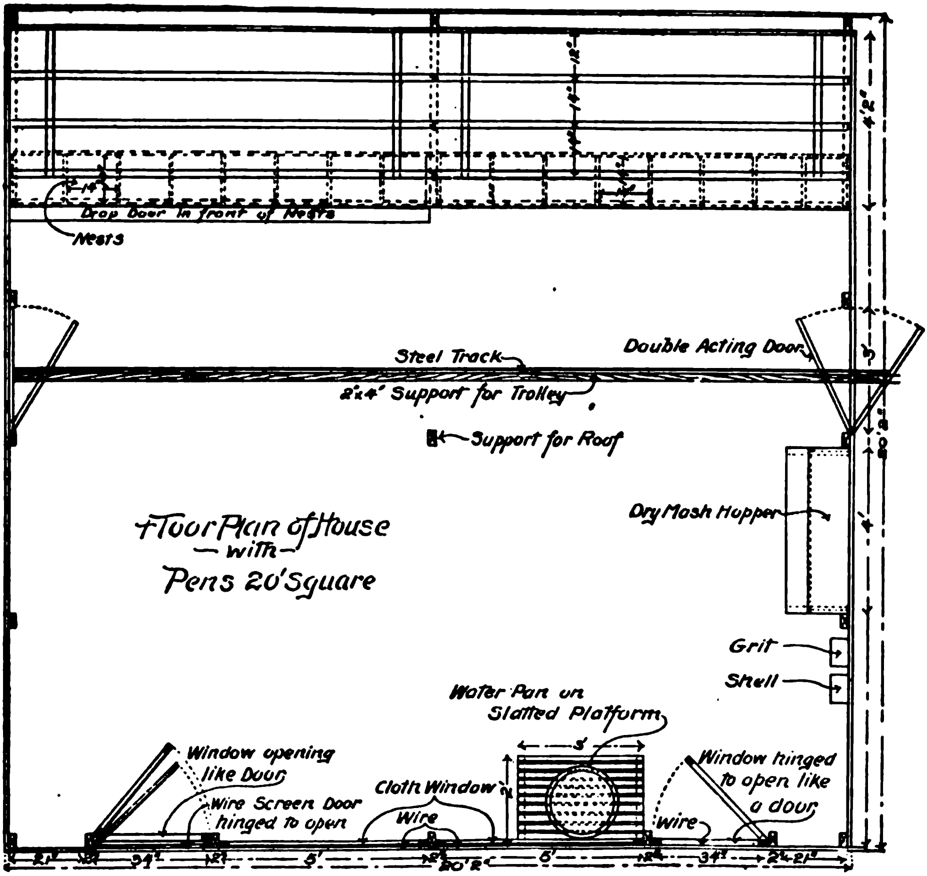

FIG. 25.— *Floor plan of a Cornell poultry house with pens 20 feet square, showing location and dimensions of interior fixtures*

however, adds to the expense of a house, and where the temperature permits it should be omitted.

In this type of house it is possible to keep the flocks separated by a complete partition of boards or a combination of cloth and boards, as illustrated in Fig. 25, or to use three-quarter partitions and allow the flocks to mix, as illustrated in Fig. 26.

In extremely cold climates it is well to use even smaller cloth curtains than are called for in Figs. 23 and 24. As an alternative, a wooden door or shutter may be hinged to close over one of the two curtains. The wooden shutter should be closed during the coldest weather only.

The construction of the 20-foot building is very similar in principle to that of the 16- and 12-foot buildings. The rear plate is placed on edge so as to allow a passage of air between the studding and the rafters. The

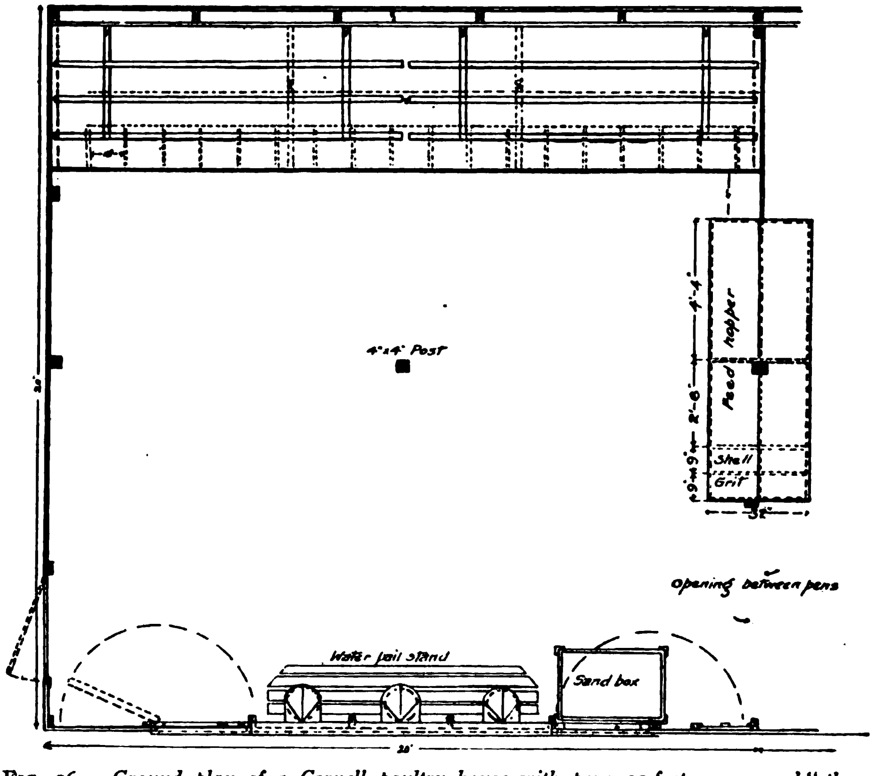

FIG. 26.—*Ground plan of a Cornell poultry house with pens 20 feet square, and "three quarter" partitions to prevent drafts and allow greater freedom to the fowls*

cloth curtains are hinged at the top, and fit tightly at the bottom over a window sill. The glass windows hinge at the side and open against the side wall, to be used as doors for cleaning. The ventilator in the back extends the entire length of the house. The ventilators in the gable ends of the house are kept open all summer, and one is kept partly open in the winter. The summer ventilators in the back are made perfectly tight during the winter.

FEED-AND-WATER CAR

The labor of caring for the fowls in a long house can be greatly lessened by the use of a feed-and-water car. The relative location of such a car

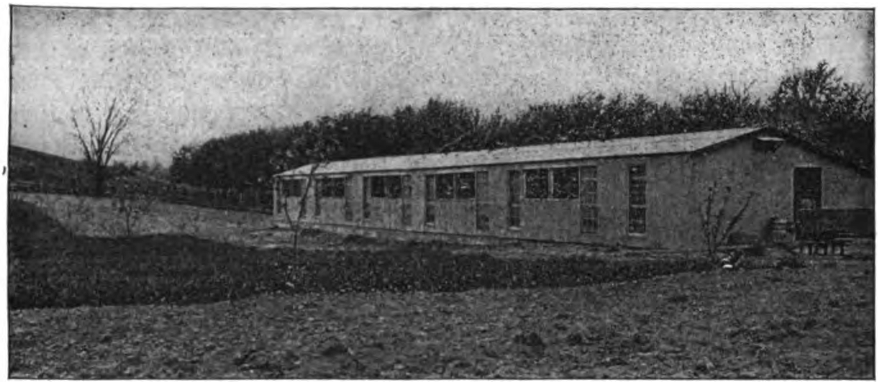

FIG. 27.— *A Cornell poultry house adapted to the combination roof. This house is 20 feet deep and 110 feet long. It has a 10-foot feed room at one end. Note the ventilator in the end*

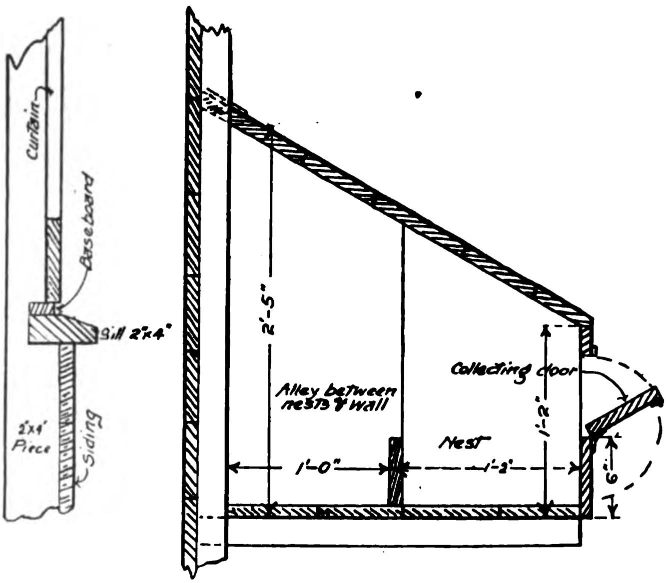

FIG. 28.— *A detailed plan of the sill and baseboard construction for a cloth curtain, and a detail of nest construction for side-wall use*

is shown in Fig. 21. There are several manufactured cars that can be used satisfactorily in such a house. The homemade car illustrated in

Fig. 29 is, in many respects, better adapted to poultry feeding and is much cheaper to install. A separate car should be used for cleaning.

SUMMARY

There is no type of poultry building best suited to all localities, or even to any one locality. Other combinations than those illustrated here can be made to meet special conditions with perhaps equal satisfaction. On farms where only a moderate-sized flock is kept, it is often unnecessary

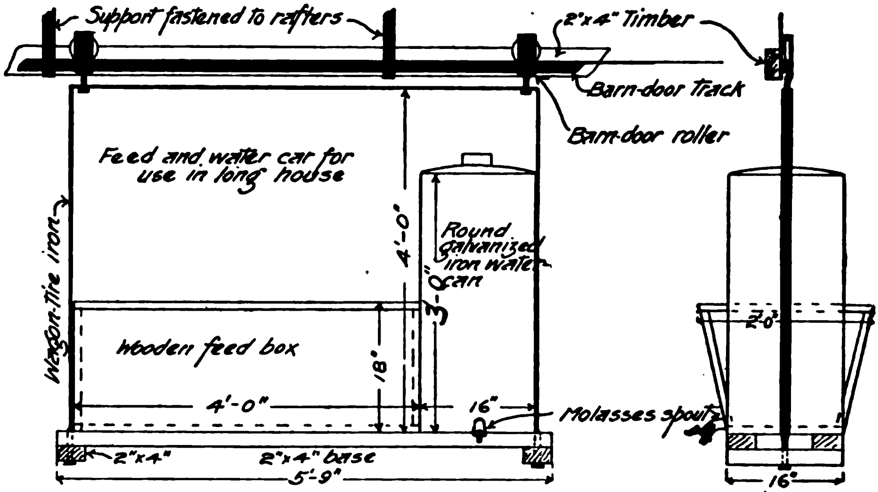

FIG. 29.— *A detailed plan of a homemade feed-and-water car, showing the method of supporting the track. Iron hangers support the 2x4-inch timbers that carry the barn-door track. The framework of the car is made of wagon-tire iron. Two roller-bearing barn-door rollers carry the car on its track. The size of the feed box and the water can may be varied in accordance with the needs of the number of fowls being fed*

to build a separate house. The barn basement, especially if it opens to the south or to the east, can be remodeled with slight expense and adapted to the needs of such a flock. The fowls can range in the barnyard during the winter and in an adjoining field during the summer. When remodeling and equipping a barn or basement, the same principles should be observed as are illustrated in the foregoing pages of this circular. Not infrequently a remodeled basement, with proper floor drainage and ventilation and with hay or straw in storage above, makes a warmer winter and a cooler summer pen, and withal a more satisfactory place for fowls, than the more elaborate poultry house.

MARCH, 1913 CIRCULAR No. 15

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Plant Physiology

LEGUME INOCULATION

MARTIN J. PRUCHA

During the past ten years much interest has been created in the use of atmospheric nitrogen by bacteria associated with the legume crops. The Department of Plant Physiology at Cornell University has received, within recent years, a considerable number of inquiries with respect to the subject. These inquiries have been particularly concerned with the introduction of the root-nodule-forming bacteria into fields. Questions respecting the "how" and the "when" to inoculate have been numerous. Many of the letters reveal the fact that the writers possess vague or erroneous ideas concerning inoculation. During the past few years the Department has been investigating the subject. In order to set forth briefly and simply the essential facts, as well as to call attention to the pure cultures that the Department is now distributing, this circular is presented to the public.

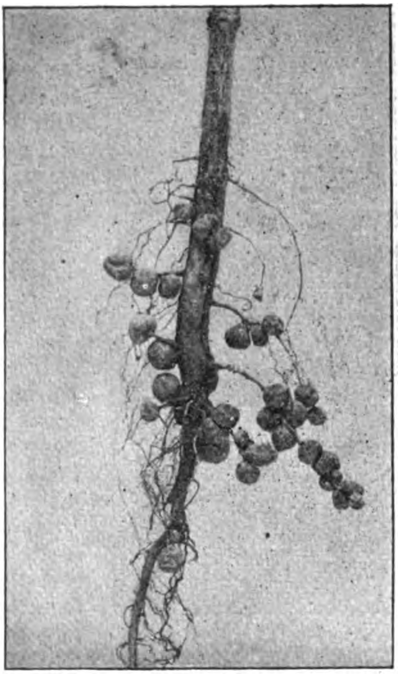

FIG. 30.—*Root of soy bean, showing nodules. Natural size*

DIFFERENCES BETWEEN LEGUMES AND OTHER PLANTS

Leguminous crops are very rich in protein. Alfalfa hay, for example, is almost as rich in nitrogen as is wheat bran. In fact, all the leguminous crops, whether in the form of hay or of seed, differ from other crops in that they are richer in nitrogen content. They are, therefore, very valuable crops.

There is another point of difference between legumes and other plants. If a leguminous plant is carefully dug up and the roots are washed, a

number of wart-like swellings may be seen on the roots. These swellings are commonly called nodules. Photographs of the roots of soy bean, alfalfa, and Canada field pea are shown in Figs. 30, 31, and 32. The nodules on the roots are of the natural size. It is seen that the size and the shape of the nodules vary with the different legumes. Under certain conditions very large nodules may develop. In Fig. 33 are shown roots of the Canada field pea grown in a loamy soil, the nodules being of the natural size.

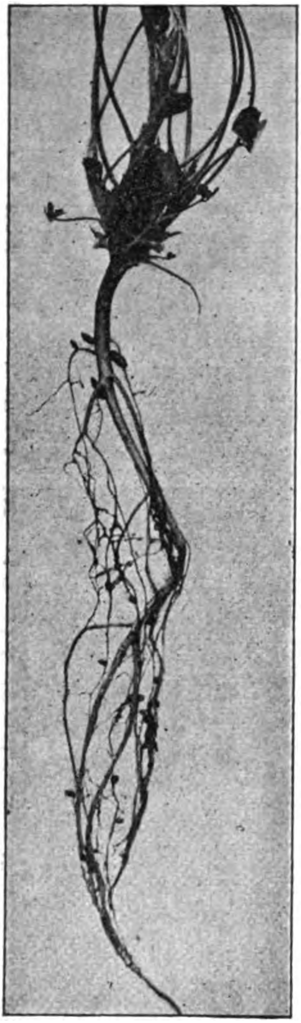

FIG. 31.—*Root of alfalfa, showing nodules. Natural size*

Another point of interest, especially to farmers, is the fact that leguminous crops seem in some way to add a little fertility to the soil on which they are grown. For many centuries past, farmers have observed that non-leguminous crops, as wheat, corn, potatoes, and the like, grown on land on which clover or some other legume was raised the year before, invariably gave a better yield. It was not understood at first, but scientific study in recent years has shown that legumes may add a certain amount of nitrogen to the soil.

There are, then, three features that distinguish leguminous crops from other crops:

1. Legume crops are very rich in nitrogen.
2. Legumes have nodules on the roots.
3. Legumes add fertility to the soil.

NODULES CAUSED BY BACTERIA

If an extremely thin slice is cut from one of the nodules and is magnified under the microscope about one thousand times, a large number of little rod-like bodies can be seen. Some of them are sausage-like in shape, and others may send out short outgrowths so that they are often called X and Y forms. These bodies are bacteria. In Fig. 34 are shown a few of the forms of the bacteria found in the legume nodule. They are living plants and, like other living organisms, they can grow and multiply. They are so small that they are not visible to the naked eye; fifteen thousand of them attached end to end would not extend more than one inch. These bacteria may live in the soil, and when they come in contact with a legume root they make their way into it and there begin to multiply. In a few days the root develops a swelling, which is a nodule, near the point where the bacteria entered. In the mature nodule are millions of these bacteria.

LEGUMINOUS PLANTS WITH NODULES ENABLED TO USE FREE NITROGEN FROM THE AIR

Chemists state that four fifths of the air is nitrogen — an unlimited supply, but the plants that are raised on our farms cannot use this nitrogen because it is a gas and is not available to them. It has been observed, however, that when nodules develop on the roots of a leguminous plant, that plant is supplied with nitrogen which comes from the air. The bacteria that produce the nodules seem to have the peculiar ability to use nitrogen from the air and in some way to supply the leguminous plant with it. It is not known how the bacteria in the nodules of the leguminous plant get nitrogen from the air, but it is known that a leguminous plant with plenty of nodules on the roots accumulates a relatively large amount of nitrogen inside its tissues, and that a certain part of this nitrogen comes from the air.

FIG. 32.— *Root of Canada field pea, showing nodules. Natural size*

Amount of nitrogen taken from the air by a leguminous crop

Since it is well known that legumes use nitrogen from the air, farmers are naturally interested to know the amount of nitrogen that may be taken from the air by a leguminous crop. This is very difficult to decide. Many experiments have been made in order to determine this, but such experiments have been performed under special conditions. The results obtained, therefore, must not be applied too closely to field conditions. One of such experiments is reported in Bulletin 147 of the Rhode Island Agricultural Experiment Station. Several different legumes were grown in special flowerpots and the amount of nitrogen was determined both in the plants and in the soil. The authors of the bulletin found that all the different legumes that they grew were able to obtain some nitrogen from the air. From their experiments they found that an acre of soy beans may take about 1,000 pounds of nitrogen from the air during a period of five years, or 200 pounds per year. Seven tenths (140 pounds) of the 200 pounds were removed in the crop, and three tenths (60 pounds) remained in the soil. Since one pound of nitrogen costs about 16 cents, 200 pounds would cost $32.

We must be cautious and not jump at the conclusion that every acre of soy beans or any other legume crop, grown in any soil and under all kinds of conditions, would take out of the air an amount of nitrogen

worth $32. In some cases it may be done, but in most cases such an amount of nitrogen is probably not removed from the air by an acre of legumes. One thing is established, however, and that is that the legumes with nodules on the roots are enabled to use a certain amount of the atmospheric nitrogen and that the legumes without nodules are not able to do so.

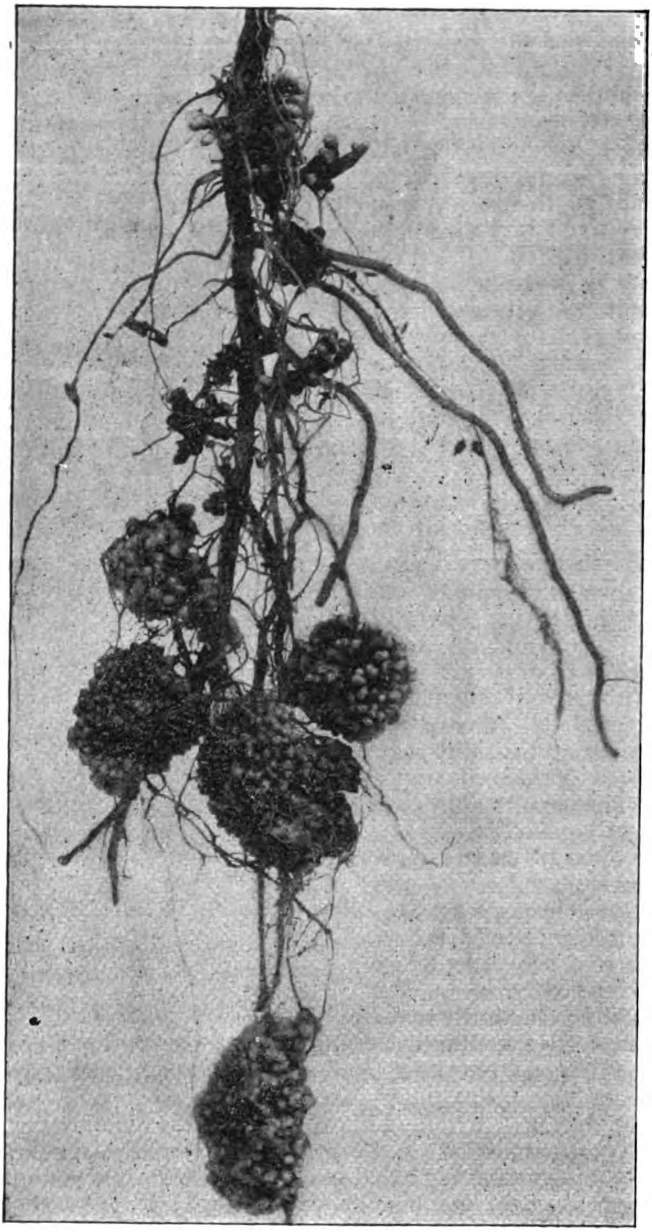

FIG. 33.— *Root of Canada field pea, showing very large nodules. Natural size*

INOCULATION

We have learned from observations that nodules may not develop on all the different legumes in all soils. From this we conclude that the bacteria which produce nodules are not always present in every field. We find that legumes such as clovers, which have been raised on almost every farm in this State for many years, generally produce plenty of nodules in most soils. Legumes such as alfalfa, soy beans, and cowpeas, however, which are relatively new crops in this State, do not generally produce nodules. Since it is the bacteria that cause the nodules, and since

legumes without nodules are not able to get any nitrogen from the air, it is to our advantage to introduce these nodule-forming bacteria into our fields. Inoculation, therefore, is the introduction into the fields of the bacteria that cause nodules on leguminous crops.

CROSS-INOCULATION

Can one legume be inoculated with the bacteria from a different legume? This question is often asked by farmers.

It seems to be well established that alfalfa can be inoculated with the bacteria from sweet clover. Successful cross-inoculation is obtained also between red clover, white clover, and alsike clover. In general it may be stated that cross-inoculation takes place between closely related legumes. Cross-inoculation is not successful between alfalfa, clover, Canada field pea, soy bean, and cowpea. But even when cross-inoculation is successful, there is no evidence to show that it is as efficient as when the legume is inoculated with its own bacteria. The information on the subject of cross-inoculation is meager and the practice is not recommended.

FIG. 34.—*Legume bacteria. Highly magnified*

HOW TO INOCULATE

There are two ways in which inoculation may be accomplished, the soil method and the pure-culture method.

Soil method

When we find nodules on a leguminous crop, we know that in the soil where the crop is being grown there are nodule-forming bacteria. If we take a certain amount of this soil and scatter it over a new field we introduce into the new field, along with the soil, some of the bacteria. In practice, usually about two hundred pounds of soil broadcasted on every acre will be sufficient to inoculate the field. This is a simple method of inoculation and good results are invariably obtained. There are, however, some drawbacks to it. It is not always easy to get the soil, and because of its bulk it is difficult of transportation. A more serious objection to the soil method of inoculation is that when the soil comes from an unknown field various weed seeds, diseases, and insects may be in it. In that case such pests would be introduced into our field and would cause trouble. Dodder, for example, may be spread in this way. Therefore one should bear this in mind when considering the use of soil for inoculation. The method is especially well adapted for inoculating one field with soil obtained from another field on the same farm.

The writer believes that the simplest and most economical way to inoculate is, not to plant and inoculate a large acreage at first, but to plant one acre or less of the particular legume and inoculate a part of it, leaving the other part uninoculated. If the plants on the inoculated part of the field look greener and healthier than those on the uninoculated part, and in addition have an abundance of nodules on the roots while the plants on the uninoculated part have no nodules or very few, the field

needs inoculation. This practice has two advantages: in the first place, the farmer learns whether the soil needs inoculation for the particular legume; and in the second place, in case inoculation is needed, the soil from the inoculated part of the field is as good inoculating material as any other. The whole farm can then be inoculated with very little cost to the farmer.

Pure-culture method

In order to make the inoculation more simple and to meet the various objections against the soil method, investigators have devised the pure-culture method. The nodule-forming bacteria are carefully removed from the nodules and are made pure. In making the nodule bacteria pure we separate them from all kinds of molds and other undesirable bacteria. When they are purified they are planted on some sterilized food in which they can multiply. In such food an extremely large number of the bacteria may develop in a few days. When the nodule bacteria are propagated in this manner the preparation is called a pure culture.

In some cultures the bacteria are propagated in liquid, in others on vegetable gelatin, and in still others unknown mixtures are employed. After considerable investigation this Department decided to employ sterilized soil as a medium in which to grow the bacteria in pure culture.

In using pure cultures for inoculation, the object to be attained is to distribute the bacteria evenly over the entire field. Two methods may be employed in order to accomplish this: (1) The pure cultures may be mixed with a certain quantity of water and then poured on the seed. The seed is stirred until each one is moistened and is then ready for planting. It is assumed that some bacteria will adhere to every seed and will be carried with it into the soil. (2) When it is not convenient to treat the seed as above described, the pure cultures may be mixed thoroughly with loamy soil, allowing about two hundred pounds of soil for each acre. The soil is then broadcasted over the field and harrowed in.

The pure-culture method of inoculation has some advantages. Being pure, there are no weed seeds, no insects, no diseases nor undesirable bacteria, provided the culture is prepared properly. It is easily obtained, easily handled, and should be cheap.

In general, a new discovery of this kind does not at first always give good results. This was true in the case of pure cultures. The reason for these failures is very simple. At first not enough was known about the nature and the habits of these nodule-forming bacteria, and consequently they were not treated properly. The result was that often, by the time the farmer procured the culture, the bacteria in it were all dead or some wrong kind of bacteria had entered into it. Investigators have learned, however, by the failures. The writer believes that at present enough is known about these bacteria to enable workers to prepare pure cultures that will give good results.

WHEN INOCULATION IS NEEDED

To inoculate each leguminous crop every time it is planted requires both labor and money, and it is a waste if inoculation is not needed. On

the other hand, if the crop is not inoculated, and inoculation is needed, the farmer loses money. So it becomes of some importance to know what leguminous crops should be inoculated.

There is only one known way by which the farmer can learn with certainty whether inoculation is needed, and that is to grow the crop in the field. If the root-nodules do not develop at all, or develop on only a few isolated plants, that leguminous crop needs inoculation when planted in that field. If, however, some nodules are present on almost every plant, inoculation is probably not needed. The simple experiment described on page 29 can be carried out by any farmer. By performing such an experiment he can readily ascertain which of the leguminous crops need inoculation when planted on his farm. To perform such an experiment, however, takes time, and many farmers may prefer to inoculate each leguminous crop rather than to take time for experimenting. Although there is no other known way of finding out with certainty as to the need for inoculation, there is a certain amount of information that is helpful in deciding the question.

Leguminous crops such as clover, peas, beans, and others that have been grown on farms in this State for many years, probably need no inoculation. There are some persons, however, who assert that it pays to inoculate every leguminous crop every time it is planted. It may be true that such a common crop as red clover may be improved by inoculation, even in New York State where it has been grown extensively for many years. It has never been proved conclusively one way or the other; but the writer's opinion, based on casual observation, is that soils on most farms in New York State are naturally well inoculated with the bacteria that produce nodules on legumes that have been repeatedly raised on the farms. On the other hand, alfalfa, soy beans, cowpeas, and any other leguminous crop that has never been raised on the farm, as a rule need to be inoculated when planted for the first time.

That inoculation is needed in most cases when alfalfa is grown for the first time has been shown in Bulletin 313 of the New York (Geneva) Agricultural Experiment Station. In one hundred and three experimental fields of alfalfa, distributed in thirty-nine counties of this State, only twenty-five were successful without inoculation. The authors say that in beginning to grow alfalfa proper inoculation of the soil is a point that is worthy of the careful attention of any farmer in this State.

WHY INOCULATION IS NOT ALWAYS SUCCESSFUL

It occasionally happens that inoculation does not produce good results. There are various reasons for this, but usually it is due to the poor quality of the culture or to the condition of the soil. The culture must not always be blamed. We all know that some crops grow well on our farms, while others may grow poorly or not at all. Bacteria are living plants, and in order to enter the roots and produce nodules they must live and multiply in the soil. There are some soils in which the bacteria will not live and no amount of inoculation will produce good results. Or it may be that the particular legume does not grow well in the soil. In either case good results from inoculation cannot be expected. The fault of the soil must first be corrected. It has been found that an application of lime — about

a ton per acre — invariably benefits certain of the leguminous crops, alfalfa in particular. In Bulletin 313 of the New York (Geneva) Agricultural Experiment Station there are given some interesting results on the benefit of lime for alfalfa. Sixty-four alfalfa fields, well distributed over the State, showed that only eleven were successful without lime, and all the fields except six were improved by the addition of lime.

STERILIZED SOIL CULTURES

As previously indicated, this Department has developed a method for distributing nodule-forming bacteria in pure culture. It has found that in sterilized soil, which it uses, these bacteria multiply readily, as many as three billion being present in an ounce of the soil. During the past two years a limited number of these cultures have been distributed, principally for experimental purposes. Because of the favorable results obtained the Department proposes to distribute the cultures for general use among the farmers of the State.

MARCH, 1913 CIRCULAR No. 16

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Poultry Husbandry

THE IMPROVED NEW YORK STATE GASOLINE-HEATED COLONY-HOUSE BROODING SYSTEM

C. A. Rogers

In this circular are described and illustrated the working plans of the New York State A-shaped colony brooder-house and its equipment for heating by gasoline. Only a few changes have been made since the publication in 1907 of Cornell University Agricultural Experiment Station Bulletin 246 on "A Gasoline-Heated Colony Brooder-House" by James E. Rice and Rolla C. Lawry, and in 1910 of Bulletin 277 of the same station on "The Principles of Brooding and the Improved New York State Gasoline-Heated Colony-House Brooding System" by J. E. Rice and C. A. Rogers.*

INTERPRETATION OF WORKING PLANS

The several plans presented herewith are designed to show, first, the more important parts of the brooder-house viewed from different directions, second, the way in which the timbers are put together, and third, the various dimensions and sizes of timbers used. Four principal plans are included, besides several detail drawings of particular features that could not be shown in the main drawings or that required more detailed outlining. The four main plans are the ground, or floor, plan; the front elevation; the rear elevation; and the side elevation.

The ground plan, Fig. 35, shows certain parts of the building as viewed from above. The positions of sills, runners, hover, windows, and door are definitely located with reference to one another. In order to show these parts to the best advantage it was necessary to leave off the roof and to remove the floor, so that one sees principally the floor timbers as viewed from above. The same illustration shows also the top view of the hover, giving its size and relative position in the house. The windows are shown by a cross-section made through the narrow dimension.

The front elevation, or end plan, or cross-section as it is more commonly called, shows the detail of the construction of studding, rafters, windows, and other parts. This is done by eliminating the siding to which the

* These bulletins are out of print.

door and windows are really fastened. The cross-section plan, Fig. 36, is the most comprehensive of the plans, showing a number of timbers and the more difficult features of construction. It marks the relative position of runners with sills and floor; of studs with plates and rafters; of door with windows and floor; and of siding with roof and runners.

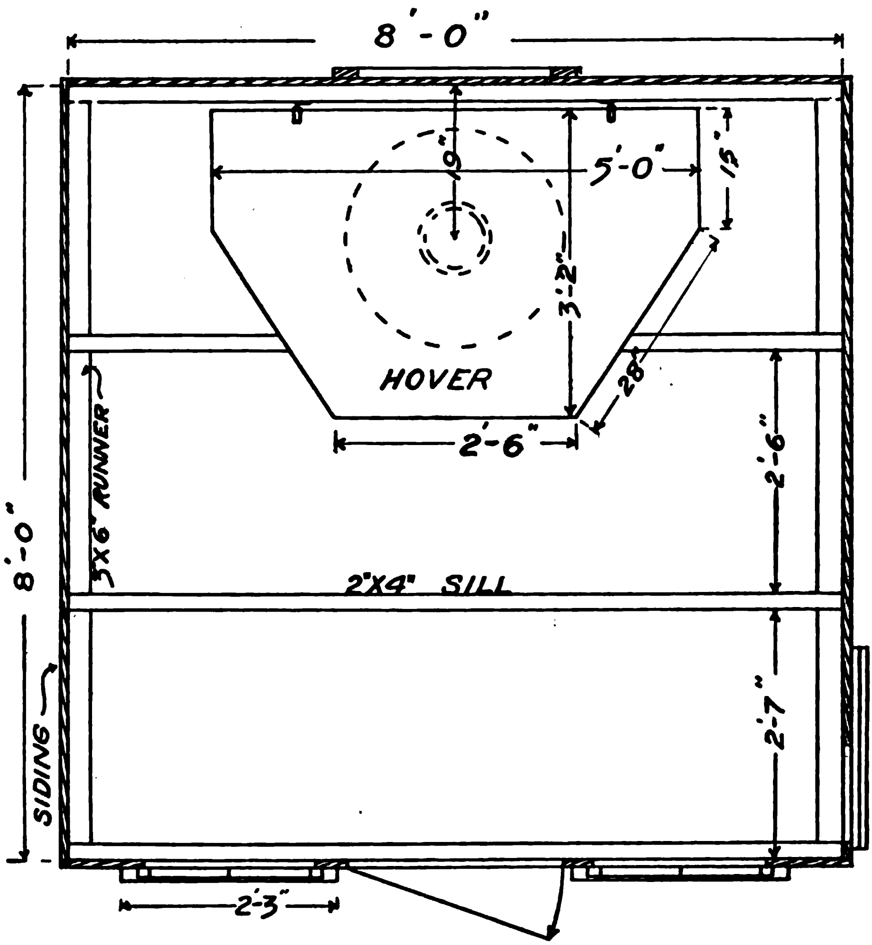

FIG. 35.—*Ground plan of the 8x8-foot colony brooder-house, showing the construction of floor timbers and the position of hover, windows, door, and exit*

The rear elevation, Fig. 37, illustrates certain details that cannot conveniently be shown in the front elevation. This plan shows the heating equipment, with the gasoline tank in the peak, the pipe connecting the tank with the heater box underneath the floor, and the radiator. It shows also the window or door in the rear. The siding is removed in this instance so as to show the interior arrangement.

The side elevation, Fig. 38, represents the building as viewed from another direction. It gives a third dimension of the timbers and of some other parts shown in the former plans; for example, in Fig. 36 the ends of the runners are seen and are shown to be 3x6 inches in size, while in Fig. 38 the lengthwise dimension is shown. Furthermore, in combination these two illustrations show that the 2x4-inch sills extend from side to side and rest on the runners, that they are not mortised into the runners, and that they are equally spaced.

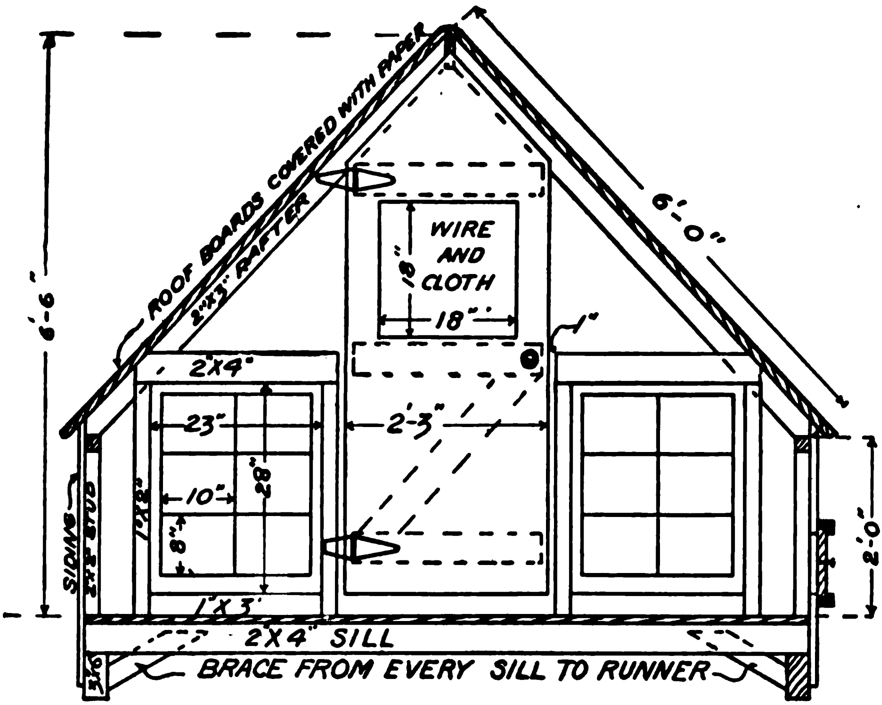

FIG. 36.—*Cross-section plan of the colony brooder-house. Note size and position of windows and door, rafters and roof, and sills and runners*

By combining these plans, therefore, the dimensions of the parts and the method of construction can be determined. Often, when the construction is complete or when one part is behind another, it is necessary to use separate detail plans such as Fig. 41 in order to make the construction clear.

In all these plans the practice is followed of showing the ends of timbers or of boards by means of shaded lines. This enables one to distinguish more easily the different timbers and their direction. When two features are shown, one directly below or beyond the other, the part that is nearer the eye is represented by solid lines and the other part by dotted lines.

The most important dimensions are given. Often a dimension that is omitted in one plan may be found in another.

CONSTRUCTION OF THE HOUSE

Floor

Two 3x6-inch runners 8 feet long, sawed as shown in Fig. 38, are placed on edge and in a level position 8 feet apart. On top of and across them are placed four 2x4-inch sills. Braces are spiked to the side of the sill and against the runners. The braces will keep the runners rigid when the house is being moved. The sides of the sills are made square with the runners and a floor of matched lumber is laid on them. The house

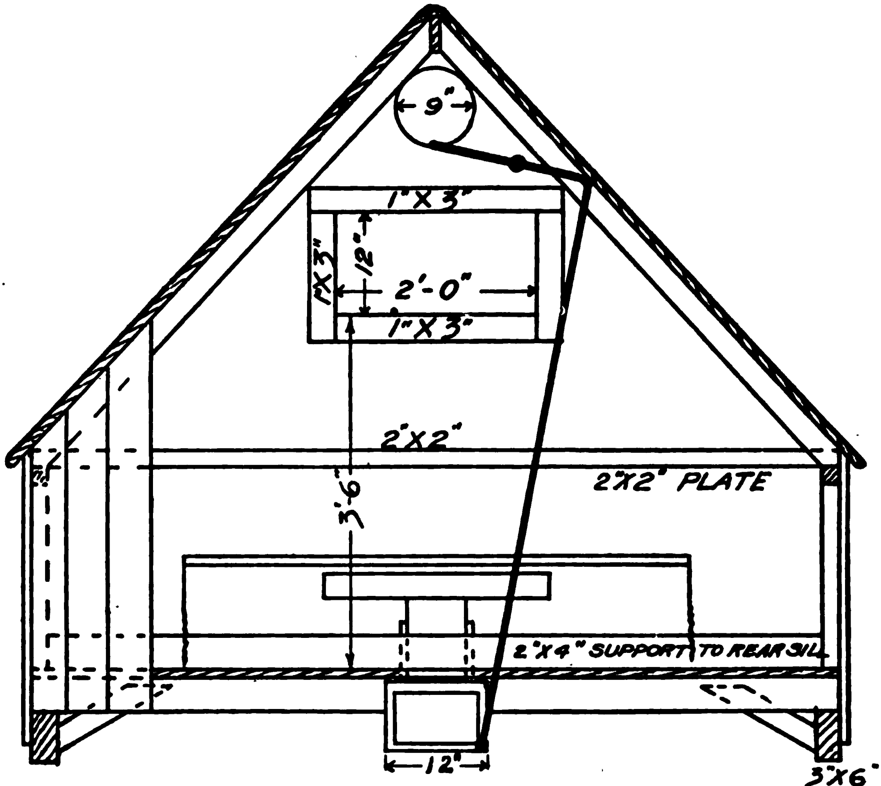

FIG. 37.—*Rear elevation of the colony brooder-house. Note the position of the heating equipment and the hover*

can be made warmer by placing building paper under the floor or by double flooring. In case the latter method is used, the first boards should be placed diagonally across the sills and the upper layer of boards square across the sills.

Studs

The studding for the sides and plates is all of 2x2-inch material. The studs may be toenailed in place on the floor directly above the sills. They should be 22 inches high. The 2-inch plates spiked to the top of the studs are 8 feet long. On each side of the door and 1 inch inside

the door opening, a 1x3-inch piece serves as a door jamb and a support for the front siding.

Bracing

The floor should be leveled; then, with square or spirit level, the studding may be plumbed and braced in both directions. The bracing should

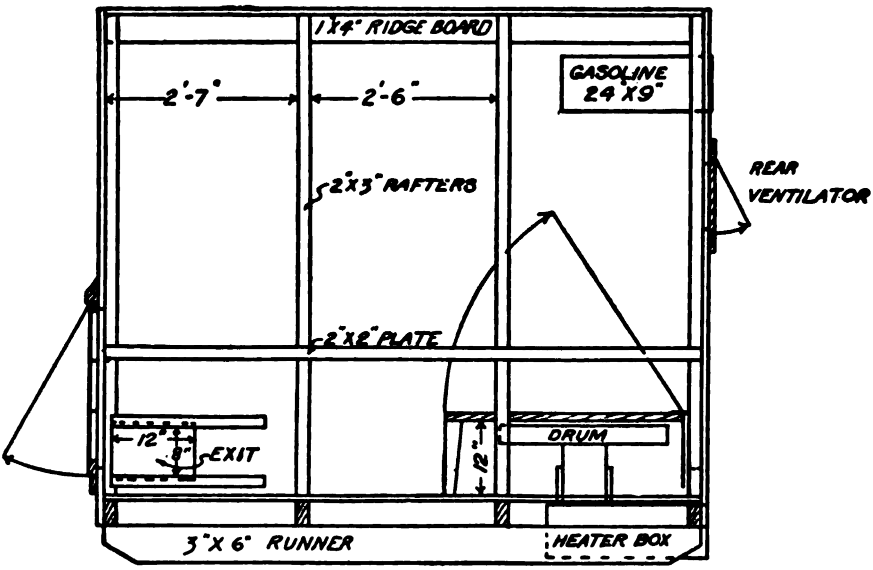

Fig. 38.—*Side elevation of the colony brooder-house, showing the distance between rafters and sills. Note the bevel at the ends of the runners, making it possible to haul the building from place to place*

all be on the inside, where it will not interfere with the laying of side and roof boards, and should be made secure enough to hold the frame in place until the building is entirely finished. The boards used for bracing can then be removed.

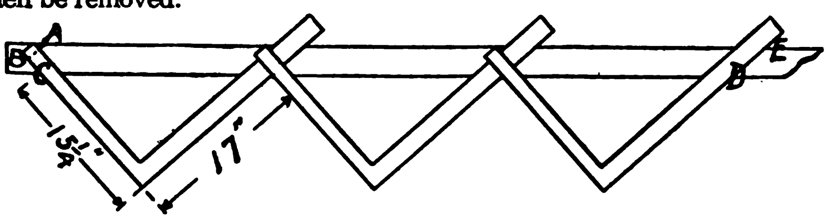

Fig. 39.—*Method of laying out the rafter with the steel square in order to get the bevel at the ends of the rafter*

Rafters

The rafters are sawed from 2x3-inch lumber and are 6 feet long. The bevel of the rafter is obtained by placing the steel square on the inside edge of the timber, at the 15¼-inch mark on one side of the square and the 17-inch mark on the other side. The square should be moved along the edge of the rafter three consecutive times, as shown in Fig. 39;

each time the $15\frac{1}{4}$-inch mark on the square should coincide with the last 17-inch point on the rafter. At the first and the last positions of the square, the lines AB, BC, and DE should be marked on the rafter to indicate the ends for sawing. AB is at right angles to BC, and B is $1\frac{3}{4}$ inches from C along the line BC. Allowance for a 1-inch ridge board has been made in these dimensions. This rafter can then be used as a pattern. The rafters are securely nailed in place, as shown in Figs. 36 and 38, and braced with boards nailed diagonally on their undersides until the roof boards are placed.

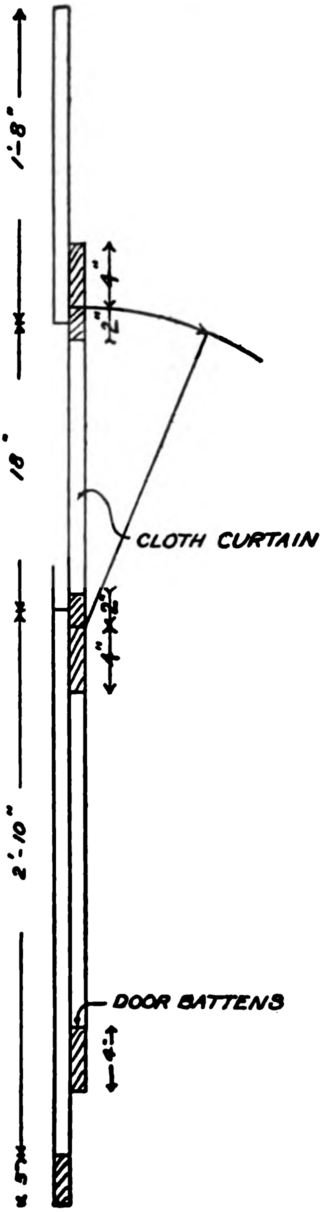

FIG. 40.—*End view of the door, showing position of battens and of cloth curtain. The other dimensions of the door are shown in Fig. 36*

Siding

Planed and matched lumber is used for all siding. It is placed vertically on the sides of the house in order to give strength to the runners. It should be nailed to the flooring. On the back of the house, also, the boards are fastened in a vertical position. Since the lower sill is cut away for the burner box, a 2x4-inch support is placed on the floor inside the rear siding, as shown in Fig. 37. The siding is nailed to this support as well as to the sill. The boards on the front of the house are placed either horizontally or vertically. The roof boards are extended two or three inches at the front, back, and bottom, so as to form projections and eaves. The roof is covered with two-ply roofing paper. For greater protection it is well to cover the sides and the ends of the house with roofing paper. This is desirable for early brooding in cold weather.

Door

The door is 2 feet 3 inches wide and 6 feet high, with its bottom 3 inches above the floor. It is exactly in the middle of the front of the house. The door is heavily hinged on the left side; it should be equipped with a hook or a window adjuster to hold it open and a latch or a clasp to hold it closed, as desired. In the upper part of the door is a muslin curtain 20 inches square, which fits between the door battens, as shown in Fig. 40, and completely covers the 18-inch-square opening in the door. The curtain is hinged at the bottom and swings down out of the way when open.

Windows

The front windows are one-sash windows, each with six lights 8x10 inches in size. Each window is placed 3 inches from the door and 3 inches above the floor. The opening over which the window fits is 1 inch smaller on all sides than the sash, as illustrated in Fig. 41. Each window is cased with a beveled 2x4-inch casing on top, 1x2-inch pieces on the sides, and a 1x3-inch piece on the bottom. The windows are hinged at the top to the 2x4-inch casing with heavy T hinges, placed near the extreme sides as shown in Fig. 41. Sash adjusters are used to hold the

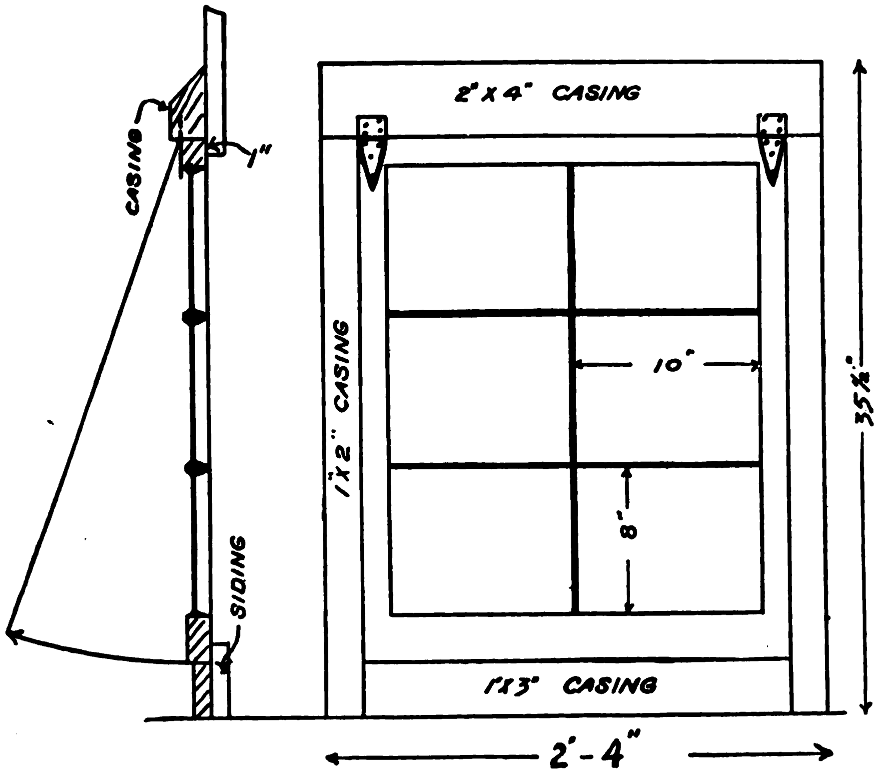

FIG. 41.— *Detail of the window, showing cross-section and front views. Note the bevel of the 2x4-inch top casing*

windows open at the desired angle. Fine-mesh poultry netting is fastened to the inside of the window casing in order to keep chickens in when the windows are open.

The window in the back can be made either of wood or of a cellar sash with three 7x9-inch panes. It is placed 3 feet 6 inches above the floor and in the middle of the back end. It is cased over the siding in the same way as the front windows, hinged at the top, and held open by sash adjusters. If the cellar sash is used a 2x4-inch casing should be used on top, otherwise the 1x3-inch casing can be used on all sides as shown in Fig. 37.

Hover

The hover is 5 feet long and 3 feet 2 inches wide, with the front corners cut back. It is held in position 3 inches from the back wall by special detachable hinges at the back and two legs at the front corners; the hinges are furnished with the heating equipment. The hover can be lifted and fastened out of the way, or it can be removed entirely. It should be level, and just high enough to clear the guards on the radiator. It can be protected from overheating by a large square of asbestos matting fastened to its lower side. Two thicknesses of table oilcloth, with the unfinished sides together and with cuts four inches apart extending from the floor halfway up, are tacked around the outside. The cuts should alternate on the two layers. When using the brooder-house in very cold weather it is well to cover the hover with roofing paper and to use a tighter, warmer cloth around the sides.

Thermometer

The thermometer furnished with the heater is hung through the hover at the side and front of the drum. One inch is the proper size of hole to make in the hover. The thermometer is made to hang about 2 to 3 inches above the floor (Fig. 42).

Exit

The exit is on the right side of the house, near the front. It is 3 inches above the floor and 8 inches high by 12 inches wide. It is closed by a slide door running between two grooved supports at the top and bottom, as shown in Figs. 36 and 38.

Heater box

The heater box is placed in the middle of the back of the house, ½ inch underneath the floor. Twelve inches of the rear sill are cut away so as to admit it. A hole 9 inches in diameter is made in the middle of the floor, with its center exactly 19 inches from the inside of the rear siding. The shoulder of the outlet in the heater box fits into this hole. The box is held in place by the sill at the back and by a wire band fastened to staples in the floor at the inner end. (Figs. 35, 37, 38, and 42.)

Drum and collars

If the floor is double-boarded, the auxiliary collar (*G-2*, Fig. 43) should be telescoped over the shoulder of the heater box. This collar can be omitted in case the floor is not double-boarded. A second collar, with a broad flange, telescopes over the other. The flange makes a tight-fitting joint with the floor. Over this in turn the perforated tin guard is telescoped. The long collar is then fitted inside the guard and over the inside shoulder on the heater box. On this collar the drum should fit tightly. In the middle of the back siding a 2-inch hole is bored at the level of the outlet to the drum for attachment of the exhaust pipes. Tin shields are placed on the inside and the outside of the hole.

Gasoline tank

A 9-inch hole is cut in the peak of the rear wall and the supply tank is passed through it (Figs 37 and 38). The tank is supported in a level position by means of wires passing around it and secured to the ridge board.

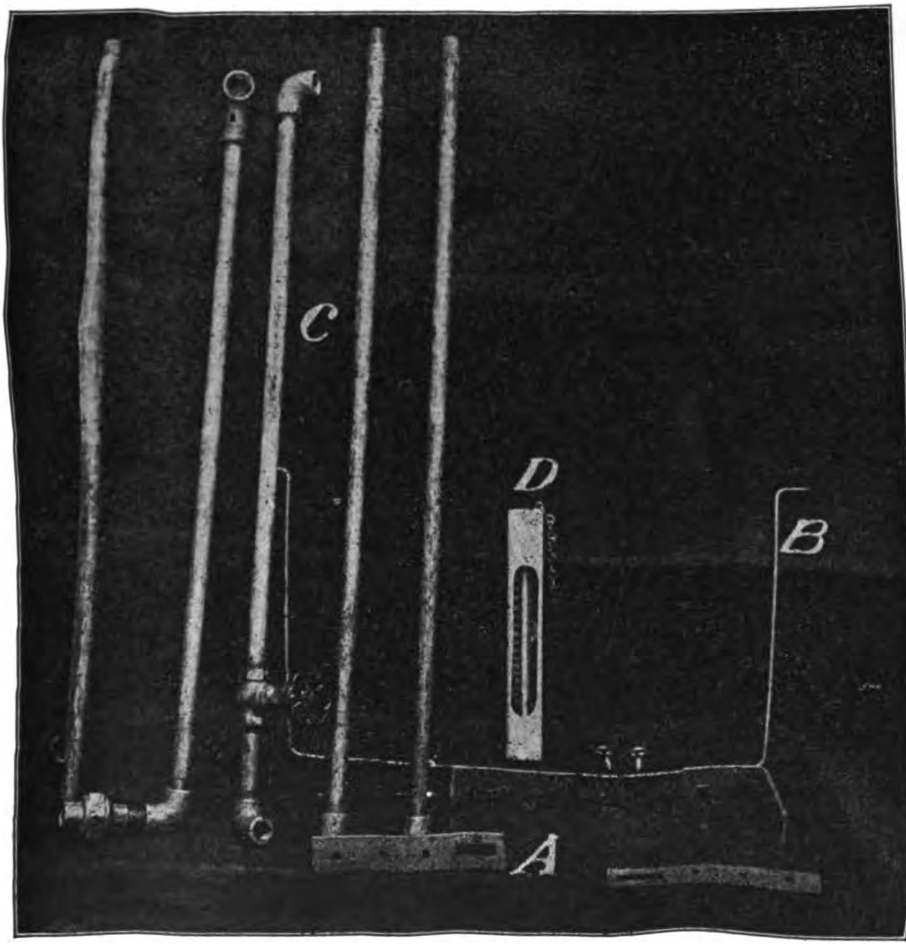

Fig. 42.—*Appurtenances to the heating equipment. A, Detachable hinges for the hover; B, wire hanger and screw eyes to hold burner box under hover; C, galvanized pipe and connections for connecting the gasoline supply tank with the burner; D, thermometer*

Pipe fittings

All threads on the pipes are now carefully soaped, and the pipe connections are made from the tank to the heater as shown in Fig. 37. Care should be taken to have all joints tight and the burner (Fig. 43) sitting square under the center of the hole, with the grate lying flat and the cover closed.

ITEMS OF LUMBER AND MATERIALS NEEDED

The following is a list of materials required for building the gasoline-heated colony brooder-house:

Runners	2 pieces 3" x 6" x 8' hard pine or hemlock
Sills	2 pieces 2" x 4" x 16' hard pine or hemlock
Casing and support	1 piece 2" x 4" x 16' hard pine or hemlock, planed
Studs and plates	5 pieces 2" x 2" x 8' planed hemlock
Rafters	4 pieces 2" x 3" x 12' planed hemlock
Single floor, sides, rear, and roof	320' hard pine or hemlock,* planed and matched in 12' or 16' lengths
Front, door, hover, casings, and door jambs	70 sq. ft. soft pine, matched and planed in any length
Roofing paper for roof	1 roll, 2-ply
Roofing paper for sides and back if desired	1 roll, 2-ply

1 pair 6" heavy strap hinges for door
3 pairs 4" medium T hinges for windows
4 sash adjusters (3 stops)
2 sashes, six 8" x 10" lights
1 sash, three 7" x 9" lights, or board door
6 ft. 24" poultry netting for windows
1 square muslin 20" x 20"
10 lbs. 8d nails for floor and siding
2 lbs. 20d nails for frame
1 lb. 6d nails for finishing
¼ lb. small wire staples
7 yds. oilcloth 54" wide
1 piece asbestos sheet 5' x 3'
1 heating apparatus

CONSTRUCTION OF THE GASOLINE HEATER

The design of the heating apparatus is illustrated in Figs. 43 and 44. *A* is the burner box, which is placed under the house and which is held in position at the back end by the opening in the rear runner and at the inside end by a wire passed entirely around it and fastened to the floor above by staples (Fig. 42). *B* is a Dangler burner.† *C* is the pipe connecting the burner with the outside pipe. This pipe is held in place by a V-shaped piece of tin at C', which centers the burner under the radiator. *D* is a drip pan to carry to the outside the gasoline that might escape in case of leakage in the pipe or when the burner unexpectedly goes out. *E* is the door in front of the burner box, through which the burner is attended. The supply of air to the burner comes through an opening in the door. A tin shield fastened 1 inch inside this opening and entirely covering it prevents the wind from blowing out the flame. Also a few holes below the door allow air to enter. *F* is the superchamber above the heater box, where the air that enters through the four ½-inch holes at the inside end is warmed by contact and sent up through the

* Various grades of lumber that are on hand or easily obtainable can be substituted.
† The Omaha burner manufactured by the Omaha Stove Repair Company, Omaha, Nebraska, is used with satisfaction by some operators. The Dangler is made by the Dangler Stove Company, Cleveland, Ohio.

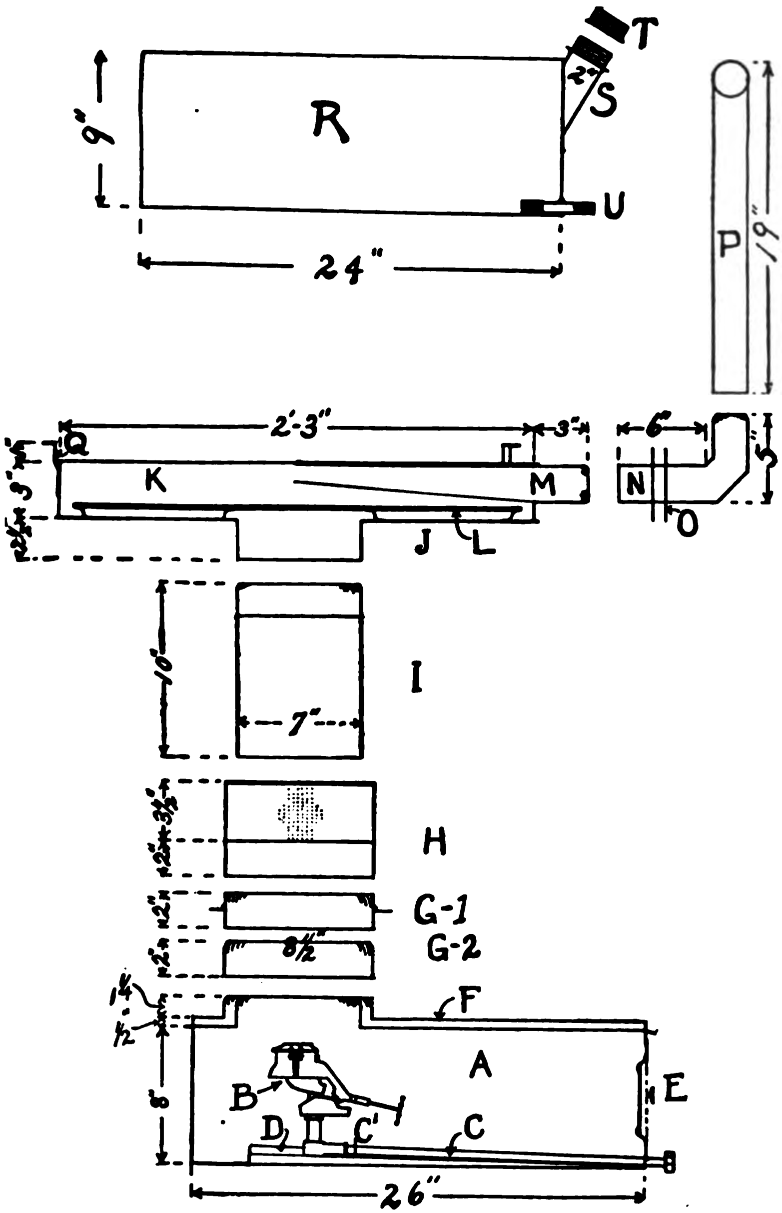

FIG. 43.— *Side elevation of the heating equipment, showing one part above another. The size and detail of each part are also shown*

perforated tin of the chick guard. It is in this way that fresh air, moderately heated, is supplied to the chicks. *G*-1 is a floor collar which fits in the hole in the floor and telescopes over the collar of the super-chamber *F*. The rim around *G*-1 should fit tightly to the floor. *G*-2 is an auxiliary collar to be used with a double floor; it lengthens the connection between *G*-1 and *F*. *H* is a chick guard which telescopes over the floor collar *G*-1, protects the chicks from the hot stem, *I*, and provides an entrance for fresh air under the hover. For convenience in shipping, it is made in a separate piece from the floor collar. The perforated tin is bent over at the top so as to close up the space between the guard *H* and the stem *I*. This prevents litter from being worked into the opening and down on the burner box. *I* is the stem that telescopes over the

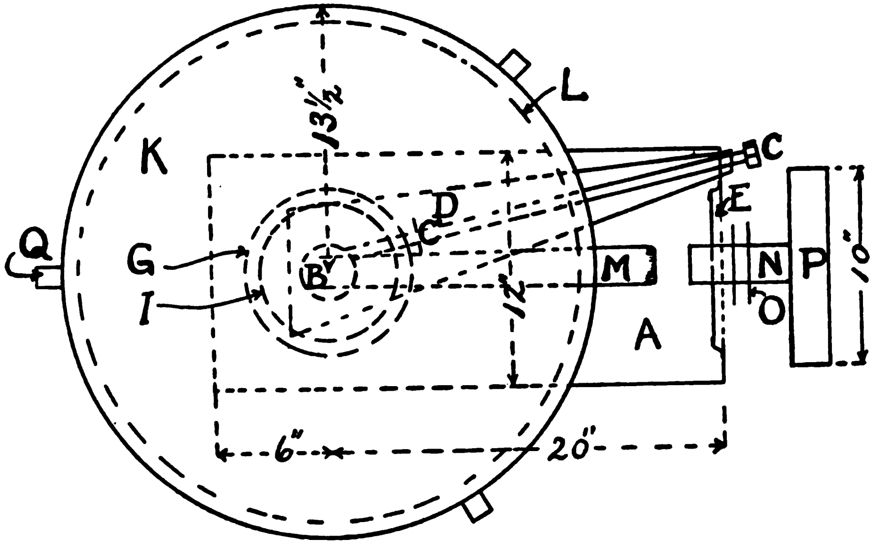

FIG. 44.—*Floor plan of the heating equipment, showing the size of drum, collars, and heating box*

collar to the burner box and connects it with the radiator. *J* is the collar to the radiator made to telescope over the stem *I*. *K* is the radiator. *L* is a diaphragm of tin surmounted with a thick mat of asbestos; it extends to within ¾ inch of the outer rim of the radiator and is supported ¾ inch above the bottom of the radiator. *M* is the outlet to the radiator. This is so arranged that the heat passing up into the radiator is spread out and reflected down on the chicks by the tin-and-asbestos diaphragm, around which it cannot escape until it is forced to the outer edge of the radiator. Before escaping entirely the air has to pass to the upper center of the radiator and then out at the outlet *M*. *N* is a connection between this outlet and the vent pipe *P*. *O* is a sheet of tin 4 inches square, with a hole in the center large enough to allow the connecting pipe N to pass through. One sheet of tin is nailed to the inside and the other to the outside of the house, in order to hold the vent pipe in place and to cover the hole through which the pipe passes. *P* is

the vent pipe, with a "T" on the end. *Q* is a guard to prevent the hover from resting on the radiator. *R* is the gasoline tank. A large square of tin fits around the outside end of this tank, the same as at *O*. A glass gauge is soldered in the end of this tank to show the height of the gasoline. *S* is the filler plug, which should have a small hole in the cap or the upper side to let air into the chamber when the gasoline recedes. *T* is the filler cap. *U* is the gasoline pipe in the lower erd of the tank, fastened in place with a strip of tin soldered over the end and to the sides of the tank.

The modified burner box, shown in detail in Fig. 46, is designed for use with either the Dangler or the Omaha burner. *A* represents the floor plan of the box, showing the five ½-inch holes, one in each corner and one near the burner. These take the place of the drip pan *D* in Fig. 43. *B* is a side elevation of the box. A small tin stop, 1 inch high and 6 inches long, is shown at *a;* the base of the burner should strike this tin in order to insure being centered under the radiator. An adjustable guide for holding the feed pipe of either the Dangler or the Omaha burner in place is shown at *b*. *C* and *D* illustrate the adjustable guide: *c* is the center groove; *d* is the thumb-screw, which passes through the bottom of the burner box and tightens on a nut soldered below to hold the guide in place; *e* is a crook in the guide for holding the feed pipe. *E* illustrates the lower front right-hand corner of the burner box. The rim is cut out enough to let the feed pipe pass in and out easily. The box is strengthened by riveting angle irons on the inside at *h*, *h*.

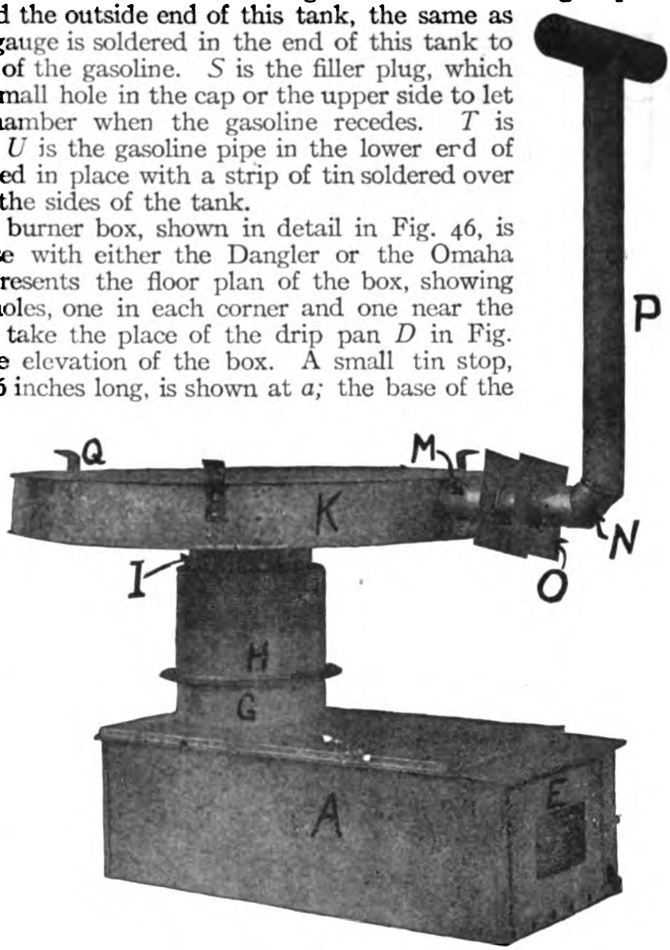

FIG. 45.— *The assembled heating apparatus, with the exception of the supply tank and the pipe connection*

The best grade of galvanized tin should be used in this heater. No solder should be used in the heater box or in the radiator, because of danger of melting. The edges of the tin should be rolled and tightly pressed together so as to make them secure and to prevent the escape of gases.

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The remaining parts furnished with the heating equipment are the thermometer, the hover hinges, and the pipe connections, as follows:

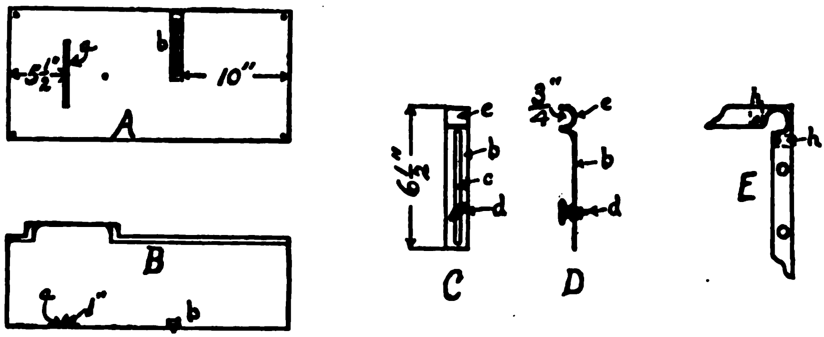

FIG. 46.—*A modified burner box, designed for use with either the Dangler or the Omaha burner*

3 lengths 22½" ¼" galvanized pipe
1 length 19" ¼" galvanized pipe
1 length 16½" ¼" galvanized pipe
1 2½" nipple ¼" galvanized pipe
1 1" nipple ¼" galvanized pipe
1 globe valve for ¼" galvanized pipe
1 union for ¼" galvanized pipe
2 couplings for ¼" galvanized pipe
3 elbows for ¼" galvanized pipe
1 brass elbow for the Dangler burner

These are all illustrated in Fig. 42.

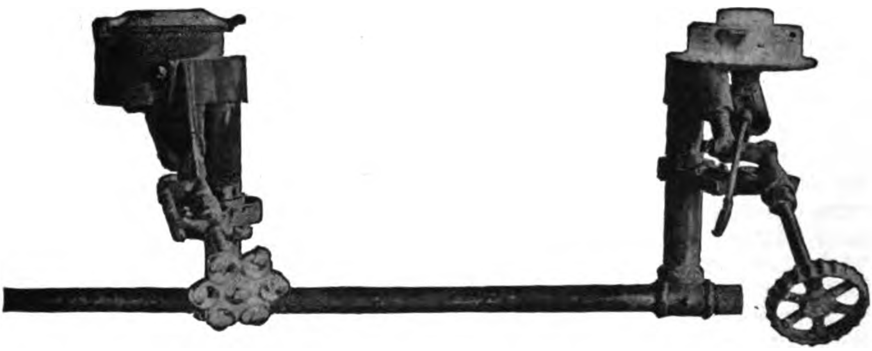

FIG. 47.— *The Dangler and Omaha gasoline burners. The Dangler is at the left and the Omaha at the right. Both are operated in the same manner, which is described on page 50. The Omaha operates more satisfactorily with poor gasoline than does the Dangler*

The gasoline brooding system that is here illustrated and described is covered by no existing patent so far as is known by the Department of Poultry Husbandry. Any person or manufacturer is free, so far as

the Department is concerned, to use these plans, but any one using them must assume all risk of litigation because of alleged infringements. This system of brooding by the use of gasoline-heated colony houses is offered free to the public, with the request that credit be given by manufactuers by placing the following statement on all heaters that they make:

Gasoline Heater
as designed and used by the
New York State College of Agriculture at Cornell University
Ithaca, New York

FACTORS THAT COMMEND THE NEW YORK STATE GASOLINE-HEATED COLONY-HOUSE BROODING SYSTEM

Heating

The heating is from three sources: first, overhead heat radiated from the radiator; second, heated air coming through the perforated tin in the chick guard; and third, sufficient bottom heat to keep the floor warm.

Ventilation under hover

A current of heated fresh air taken through the superchamber in the burner box is constantly forced under the hover, thereby insuring an abundance of pure air.

Ventilation in house

With the muslin curtain, the windows in the front, and the window in the back, the air in the house can be kept fresh in summer or winter. There is no burner inside the house to consume the fresh air. The fumes of combustion are all carried away; none are discharged inside the house.

Temperature

The choice of several temperatures materially aids the development and growth of a chicken. Several different degrees are possible in this house — a high one under the drum, a medium one at the edge of the hover, and a moderate one outside the hover. The chicks work and eat in the moderate, or cooler, temperature and sleep in the medium and warm temperatures.

Adaptability

It is detrimental to the growth of chickens to change them from house to house. This colony-house system will accommodate the chickens from shell to maturity, by substituting perches for hover when the chickens no longer need heat and by removing the cockerels as soon as they are half grown.

In winter the house can be used for surplus stock, for breeding cockerels, pullets, or hens for sale, and even for a pen of layers. Several of the colony-houses can be connected, as shown in Figs. 48 and 49, and house

a moderately large flock, although it is not generally practicable to use brooder-houses for laying stock. When equipped for layers, perches and platform should be added (Figs. 50 and 51.)

FIG. 48.—*Method of joining two houses. The house shown is different in a few details from the one described in this circular*

Capacity

Exercise for the chicks is exceedingly important. More room for working and for feeding is provided in this house than in the small fifty-to-one-hundred-chick brooders or even in the separate pen of a long brooder-house. Unlike small brooders, this house provides enough room for the feeder to work inside the house. At the same time it has the advantage that opening the door causes less change in temperature than in the small brooder. The colony-house easily accommodates two hundred and fifty chicks. A smaller number can be brooded as easily, and on some occasions many more have been successfully brooded at one time.

Economy

The cost for fuel is higher for this house than for the small kerosene brooders of equal capacity or for coal-heated brooders, but the labor required in caring for chicks in the colony-house is many times less than in several kerosene brooders of like total capacity. The labor cost is less in the long-house brooder, but the cost of construction and equipment is greater and the season of usefulness is shorter. The fuel capacity is sufficient to supply the heater for several days and the burner requires but little attention.

FIG. 49.—*Galvanized collar with adjustable shoulders, used to connect two houses and provide a runway between two pens*

Portability

In the rearing of chickens fresh ground is exceedingly desirable. It is difficult to keep the ground in fresh condition when it is used year after year, and especially when a large number of chicks are placed on a comparatively small area. The colony brooder can easily be moved to fresh pasture by a team of horses. In Fig. 52 is shown a colony-house in a cornfield, an admirable place for chickens. It is so constructed that it can be drawn on its own runners or elevated upon a truck or skids. If drawn on its own runners it travels end first and easily passes between large trees in an orchard.

MANAGEMENT

The management of the New York State colony brooder is simple and easy. If a few rules and principles are followed, the operation of the system is perfectly safe.

Position of house

Ordinarily it is preferable to face the front of the house toward the south or southeast. However, if the prevailing winds are from the south or southwest it is better to face the front toward the east. Frequently, also, the slope of the ground and the convenience of the feeder make it more desirable to face toward the east rather than toward the south.

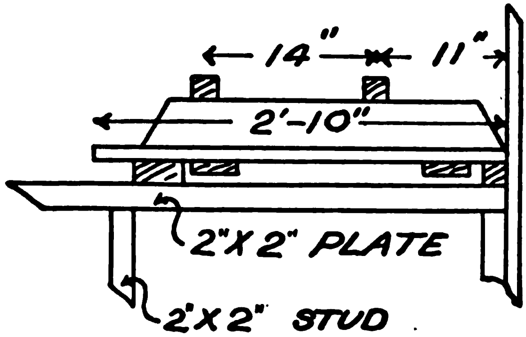

Fig. 50.— *Front view of the perches and platform, showing their position in the rear of the house. The platform is made in two sections, which divide in the middle so as to make possible its removal from the building*

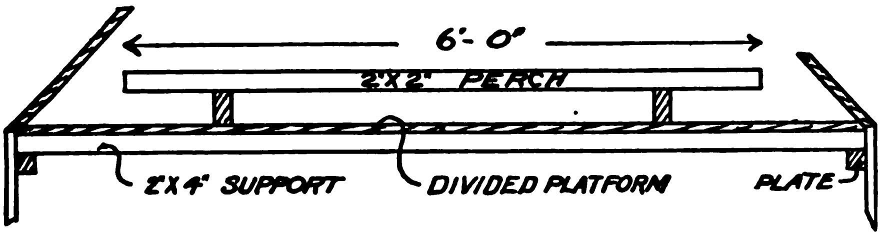

Fig. 51.— *Sectional drawing of the back part of the house, showing perch and platform construction as arranged for a pen of layers. Note the loose 2x4-inch support to the platform resting on the two plates. The perches are fastened to a 2x4-inch support on edge, which rests on the platform. See Fig. 50*

The building should be carefully leveled, in order to get an even distribution of heat in the building and under the hover. This leveling also facilitates the operation of the burner.

Windows

The muslin curtain in the door will allow sufficient ventilation during cold days and nights. During warmer weather it is necessary to open either the front glass windows or the rear window, and in extremely warm weather to open all windows and door. As a rule, however, the rear window should be closed during moderate weather while the front windows are open, in order to avoid risk of too strong circulation.

During a head wind it often becomes necessary to close all the front windows and curtains and slightly open the rear window. This practice allows the wind that enters through the curtain and the cracks in the front

wall to escape through the back window, instead of blowing down through the ventilating space in the heater and taking much of the heat with it.

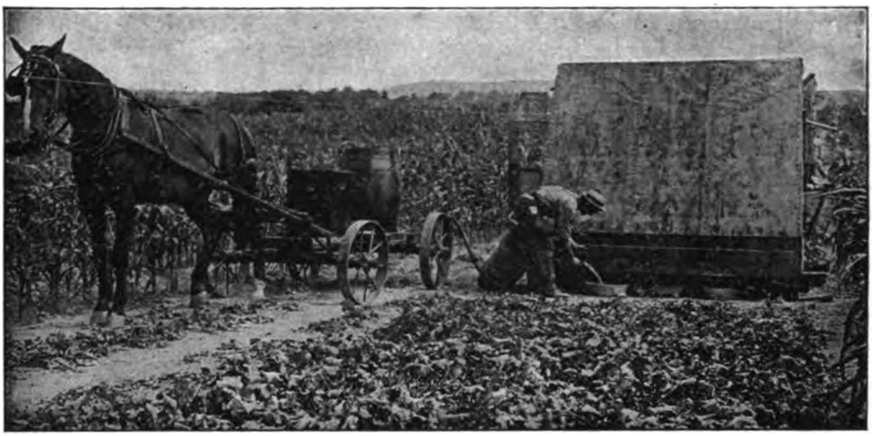

FIG. 52.— *Use of the colony-house for growing pullets. The house is located in a cornfield, with plots of rape planted near by. A horse and wagon makes the work lighter and quicker. The house shown in the picture represents an older type than the one described in this circular*

Lighting the burner

The parts of the Dangler burner are illustrated in Fig. 53. The following directions should be observed in its operation:

Turn on the gasoline supply at the valve in the pipe line. Open the control valve, CV, in the burner and allow the generating cup, GC, to become filled with gasoline. Close the control valve. Light the gasoline and allow it to burn itself out. In doing so it will heat the oven of the burner and vaporize the gasoline passing through it. Again open the control valve. Gas instead of gasoline will come out of it. Ignite the gas at the top of the heater, or cone, C, so that the flame will be above it, not under. If the flame back-fires and burns from beneath, close the valve for a moment, then reopen and ignite.

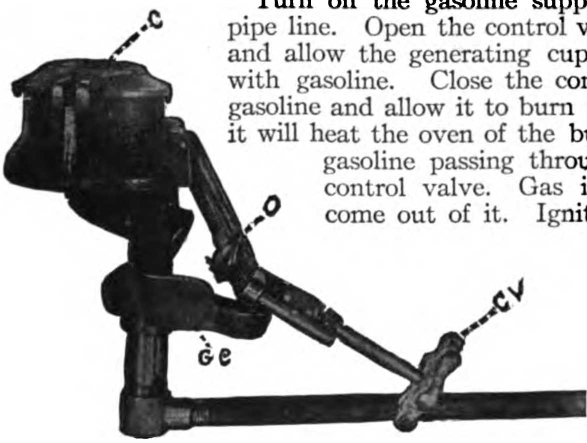

FIG. 53.— *The Dangler furnace and laboratory lamp burner No. 154: CV, control valve; GC, generating cup; O, small opening in valve seat; C, cone*

Should the flame become extinguished through lack of gasoline or because of water or dirt in the gasoline, do not immediately relight. First close the control valve. If gasoline has run over into the burner

box, be sure to wipe it up carefully and to allow the fumes to escape before relighting. If the burner is very warm, allow it to cool before attempting to relight. If the burner is still hot enough to generate gas it can be relighted at once; but if it is only warm enough to partly vaporize the gasoline there is danger of a slight explosion, which will usually do no more harm than to startle the operator and perhaps to singe the hair from his hand or eyebrows.

Gasoline

A mistake very generally made is in using common and poor grades of gasoline. The Dangler or Omaha furnace burners that are used in this system soon become clogged if the gasoline contains much kerosene. The flame is extinguished if there is water in the gasoline. The lighter grades of gasoline are best. Gasoline with a specific gravity test of less than 68 or 72 should not be used. A gravity test of 76 is still better, but the additional cost is greater than the increased efficiency. Motor gasoline tests about 62. A special hydrometer for testing gasoline is illustrated in Fig. 54. Such a hydrometer can be obtained at the average garage or can be bought for 75 cents to $1.50.

In case water is present it can be detected when the burner is lighted. If there is a sputtering when the gasoline is burning in the generating cup, this is due to the boiling of water in the gasoline. The water can be removed by straining the gasoline through a piece of chamois leather.

If the gasoline is heavy, this will be shown by yellow streaks in the flame. The flame should be a deep blue or green, without yellow. If the flame shows much yellow there is danger that the burner will become clogged and will fail to work.

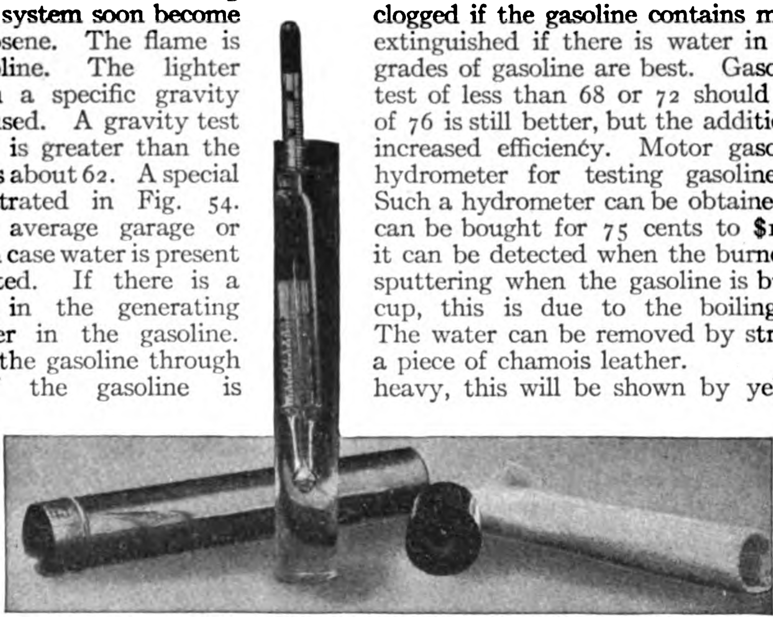

FIG. 54.—*A hydrometer for testing gasoline, a glass container, and a carrying case. The upper scale indicates the specific gravity of the gasoline at 60° F. The right lower scale indicates the temperature of the gasoline in degrees Fahrenheit. The left lower scale shows the amount to be added when the temperature is below 60° F. and the amount to be subtracted when the temperature is above 60° F.*

If the gasoline is poor the burner will frequently back-fire and burn from below. Occasionally this fault is due to poor packing in the burner or to a clogging in the pipe system, but more often it is due to poor gasoline. Repeated and constant difficulty will be experienced and the burners will be condemned as useless unless good gasoline is used.

Use of other types of houses

This heater can be installed in other houses than those of the A-shaped type. Care should be taken to have the supply tank placed as high as

in the A-shaped house, that is, with at least 6 feet between the bottom of the tank and the bottom of the burner box. The higher the tank is, the better the flame will be. If the capacity of the house greatly exceeds that of the A-shaped house, it would be well to install two heaters, or to have the house of very tight construction with ventilation under perfect control, or to use the house during the warm spring months only. The supply tank should not be exposed to the weather; the hot sun would increase the evaporation, causing the sides of the tank to cave in.

Cautionary measures

Do not allow the burner to become shifted from under the center of the flue or to lean toward one side.

Do not have the small grate in the top of the burner oven tipped on edge.

Do not relight the burner when it is warm.

Do not relight the burner when there is gasoline on the floor of the burner box.

Do not use poor gasoline.

Do not have the house out of level.

RECOMMENDATIONS

The improved New York State colony brooding system is highly recommended for brooding chickens under conditions of free range. It is equally suitable for use singly when only one hatch is to be reared, or in a series where several thousand chickens are to be reared. It is not recommended for winter brooding, but is best suited for brooding during the natural brooding season — the months of March, April, and May. It provides conditions that are healthful, sanitary, and conducive to the production of vigorous stock.

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Animal Husbandry

THE FORMATION OF COW-TESTING ASSOCIATIONS

HENRY H. WING

In this State during the past twenty years notable advances have been made in the practice of feeding animals, particularly dairy cows. At the present time it may be said that the majority of dairymen are feeding their cows with intelligence and skill. On the other hand, it must be recognized that the average production of the dairy cow in this State is not large enough to furnish a satisfactory revenue to her owner. Undoubtedly, one reason for this condition is that comparatively few dairymen give much attention to the selection of their cows, and scarcely any keep records of individual production on which to base selection for breeding purposes. There are good reasons for believing that the same attention given to records of production, selection, and careful, systematic breeding from improved sires would result in quite as much benefit to the dairymen as has been secured by greater attention to the principles of feeding, as indicated above.

PRODUCTION OF MILK IN 1899 AND 1909 IN NEW YORK STATE

The most readily available data concerning the production of cows in the State of New York are drawn from the reports of the Twelfth Census in 1900 and the Thirteenth Census in 1910. We find that in 1899 there were 1,501,608 cows in the State and that their average production of milk was 4,378 pounds. In 1909, there were 1,509,594 cows in the State with an average production of milk of 4,410 pounds, which shows that in number of cows and in average production there had been practically no change in ten years.

Wide variations in certain counties

While these statistics for the State as a whole have remained nearly stationary, there have been notable variations in many of the counties. These changes are apparent not so much in the number of cows kept, as in the increase and decrease of the average production of milk. The following table shows for each county in the State the number of cows, the average production of milk in 1899 and 1909, the increase or decrease in production, and the relative rank of the county at the beginning and at the close of the decade:

TABLE I. DATA OF MILK PRODUCTION FOR 1899 AND 1909

County	Total number of cows, 1909	Average yield in pounds, 1899	Average yield in pounds, 1909	Increase or decrease	Rank in yield per cow	
					1899	1909
Albany	13,483	5,085	4,599	—486	12	19
Allegany	39,573	3,724	4,208	484	55	37
Broome	29,648	4,229	4,690	461	37	16
Cattaraugus	59,779	4,286	4,196	—90	35	38
Cayuga	27,199	4,817	4,387	—430	18	26
Chautauqua	49,648	4,066	4,004	—62	46	48
Chemung	11,035	4,508	4,270	—238	31	33
Chenango	50,711	4,593	5,013	420	27	10
Clinton	25,032	3,448	3,462	14	61	60
Columbia	16,126	4,571	4,094	—477	29	43
Cortland	27,427	4,161	4,882	721	40	14
Delaware	78,073	4,854	4,476	—378	16	24
Dutchess	31,241	4,975	5,103	128	14	9
Erie	44,331	4,784	4,689	—95	21	17
Essex	10,634	3,657	3,953	296	56	51
Franklin	28,964	3,599	3,735	136	58	58
Fulton	9,835	3,837	3,913	76	53	53
Genesee	13,768	4,842	4,260	—582	17	34
Greene	15,423	5,261	4,179	—1,082	6	40
Hamilton	1,183	3,635	3,754	119	57	57
Herkimer	40,423	4,066	4,572	506	47	21
Jefferson	64,855	4,284	4,310	26	36	29
Kings	113	3,541	7,140	3,599	59	2
Lewis	36,291	3,929	4,317	388	50	28
Livingston	17,859	4,700	4,363	—337	23	27
Madison	36,994	4,679	5,146	467	25	6
Monroe	17,198	5,272	4,301	—971	5	30
Montgomery	22,804	4,212	4,895	683	39	13
Nassau	2,389	4,073	4,761	688	45	15
New York	266	5,535	5,808	273	2	4
Niagara	13,058	5,181	3,967	—1,214	9	49
Oneida	64,779	3,839	4,595	756	52	20
Onondaga	36,330	4,694	4,925	231	24	12
Ontario	13,272	5,239	4,102	—1,137	8	42
Orange	45,882	5,388	5,723	335	3	5
Orleans	7,247	4,593	3,830	—763	28	54
Oswego	40,774	3,787	4,187	400	54	39
Otsego	52,920	4,224	4,502	278	38	23
Putnam	8,425	5,306	5,127	—179	4	8
Queens	1,968	6,249	8,151	1,902	1	1
Rensselaer	19,804	4,798	4,294	—504	20	31
Richmond	704	5,136	6,698	1,562	11	3
Rockland	2,268	4,408	4,272	—136	33	32
St. Lawrence	100,537	4,004	4,027	23	48	47
Saratoga	16,224	4,388	3,777	—611	34	55
Schenectady	4,929	4,568	4,244	—324	30	36
Schoharie	26,138	4,882	4,474	—408	15	25
Schuyler	5,945	5,005	4,610	—395	13	18
Seneca	7,439	5,159	4,123	—1,036	10	41
Steuben	37,599	4,002	3,717	—285	49	59
Suffolk	5,996	4,104	3,958	—146	42	50
Sullivan	21,230	3,505	3,425	—80	60	61

TABLE 1 (*concluded*)

County	Total number of cows, 1909	Average yield in pounds, 1899	Average yield in pounds, 1909	Increase or decrease	Rank in yield per cow	
					1899	1909
Tioga	16,430	4,641	4,962	321	26	11
Tompkins	15,008	4,802	4,562	—240	19	22
Ulster	23,065	4,124	3,942	+182	41	52
Warren	5,397	3,851	3,771	—80	51	56
Washington	28,169	4,103	4,075	—28	43	46
Wayne	20,645	4,459	4,089	—370	32	44
Westchester	11,475	4,709	5,139	430	22	7
Wyoming	28,066	4,097	4,247	150	44	35
Yates	5,566	5,240	4,085	—1,155	7	45

Some of the wide variations shown in the above table, particularly in those counties that have a small number of cows, may be due to errors made in taking the census, but without doubt the figures give a fairly accurate idea of the average production of dairy cows. In looking over the table the reader will notice that those counties which have the largest number of cows and give most attention to dairying are, in most cases, the counties in which the largest gains were made between 1900 and 1910.

Influence of purely bred stock

It is also of interest to inquire as to the effect that the introduction of purely bred animals may have had on the average dairy production. The number of purely bred dairy cattle has increased rapidly in the last ten years, as the records of the various herdbook associations show; but, as the federal census has never attempted to gather statistics of purely bred animals, there is no direct means of making such comparison. In 1910 the Commissioner of Agriculture of the State of New York gathered and published as complete a list as possible of the purely bred live-stock in the State.* The figures published in this bulletin are confessedly incomplete, but there is no reason to believe that they are not relatively applicable to all parts of the State. It is likewise reasonable to suppose that in those parts of the State where the most pure-breds are found, there is to be found also the greatest proportion of grade animals of the same breed. The twenty counties in the State having the largest number of dairy cows include 969,352 of the total of 1,509,594 cows, or nearly two thirds of the whole. If these counties are arranged, then, in order of highest percentage of pure-bred cattle to dairy cows, the following table results:

* Bulletin 17, New York State Department of Agriculture. A partial list of the owners of pure-bred live-stock in New York State. By Raymond A. Pearson.

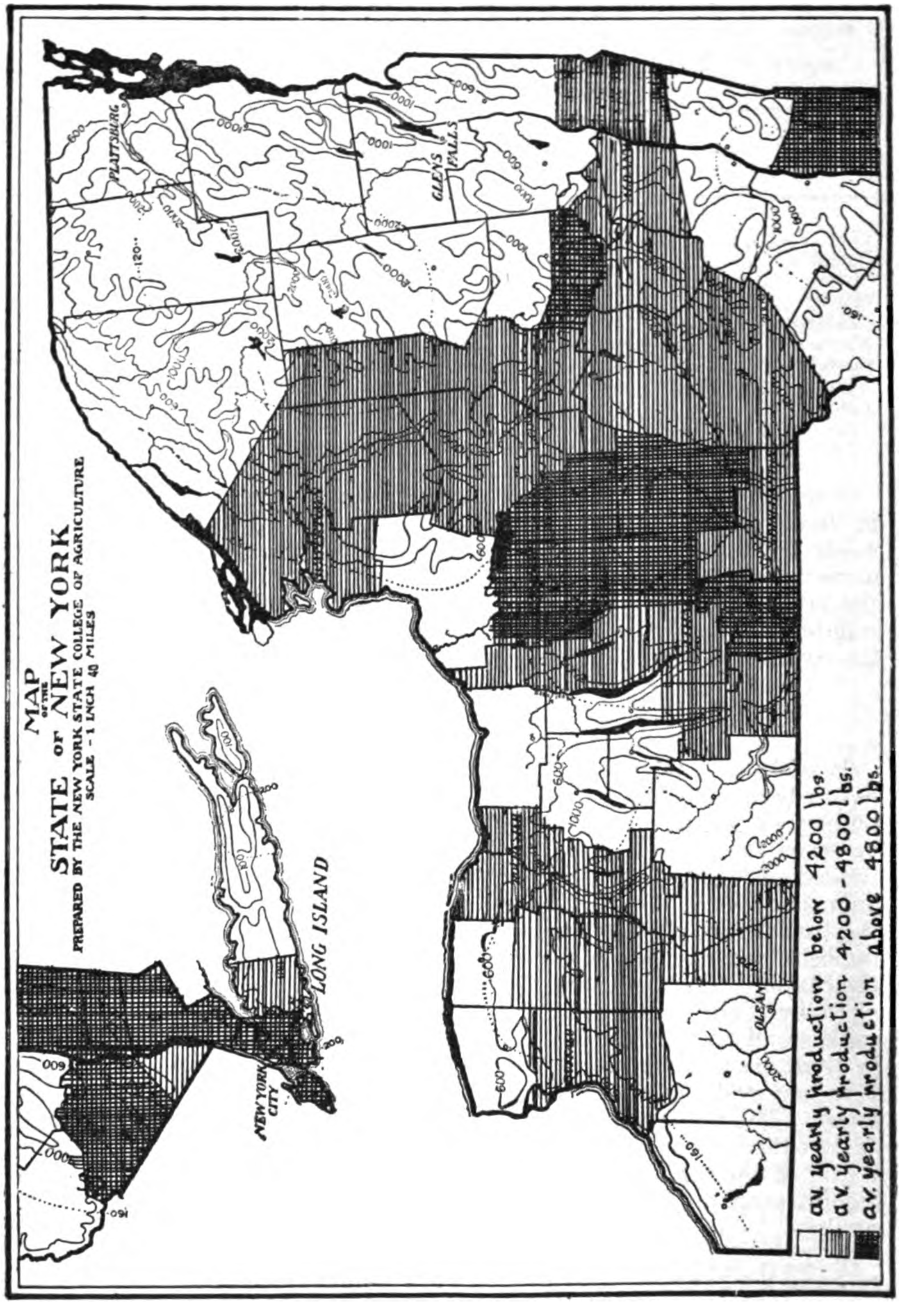

FIG. 55.—*Annual milk production per cow in New York State, by counties*

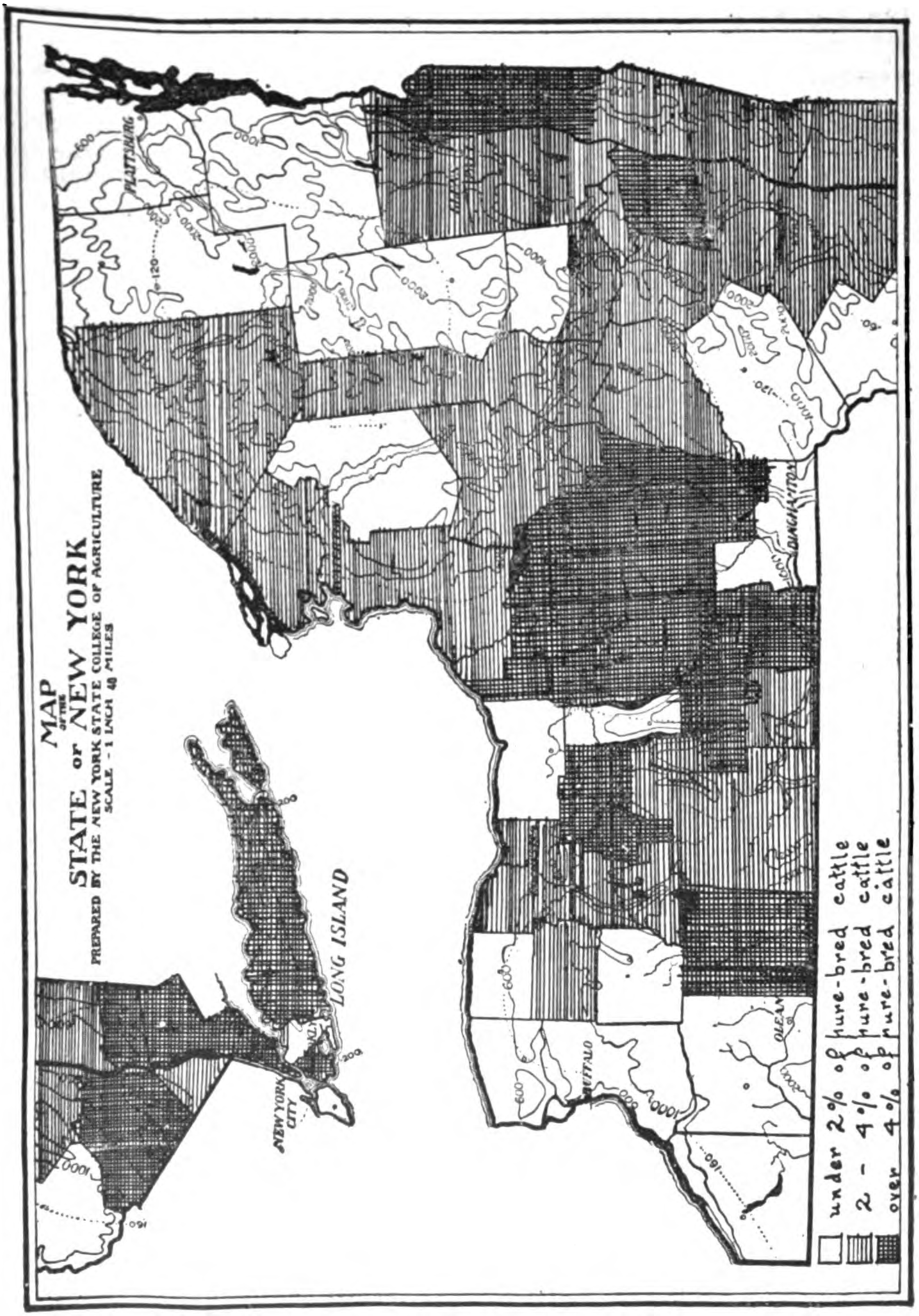

FIG. 56.—*Percentage of pure-bred cattle to dairy cows in New York State, by counties*

TABLE 2. RELATION OF INCREASE IN PRODUCTION TO PERCENTAGE OF PURE-BRED CATTLE

County	Number of dairy cows	Number of pure-bred cattle	Percentage of pure-bred cattle to dairy cows	Average yield per cow, 1910 (pounds of milk)	Increase 1900–1910
Madison	36,994	3,866	10.45	5,146	467
Onondaga	36,330	2,507	6.90	4,925	231
Allegany	39,573	1,976	4.99	4,208	484
Orange	45,882	2,221	4.84	5,723	335
Chenango	50,711	2,049	4.04	5,013	420
Otsego	52,920	1,905	3.60	4,502	278
Dutchess	31,241	1,120	3.58	5,103	128
Oswego	40,774	1,302	3.19	4,187	400
Jefferson	64,855	2,015	3.11	4,310	26
Herkimer	40,423	1,175	2.91	4,572	506
Steuben	37,599	1,064	2.83	3,717	—285
Oneida	64,779	1,691	2.61	4,595	756
St. Lawrence	100,537	2,371	2.35	4,027	23
Erie	44,331	775	1.75	4,689	—95
Chautauqua	49,648	772	1.55	4,004	—62
Lewis	36,291	516	1.42	4,317	388
Delaware	78,073	1,109	1.42	4,476	—378
Cattaraugus	59,779	838	1.40	4,196	—90
Broome	29,648	331	1.12	4,690	461
Franklin	28,964	273	0.94	3,735	136

The table shows clearly the influence of purely bred animals. The counties containing the largest proportion of pure-breds include the counties in which the average yield was highest and the counties which made the largest increase in yield during the ten years. Of the ten counties having the highest percentage of purely bred animals, all but one made a notable increase from 1900 to 1910; while in the ten counties containing the smallest proportion of pure-breds, five showed a distinct loss and only three showed a considerable gain.

NECESSITY FOR HIGH-PRODUCING ANIMALS

In order to determine whether or not the average cow is profitable to her owner, it is necessary to make a calculation of the value of her product and the cost of maintenance for a year. Lacking accurate data for a large number of individuals, such a calculation must be largely in the nature of an estimate, and it is governed to a considerable extent by local market fluctuations in prices of food and dairy products. The following is therefore given as an estimate, to be varied in any respect as particular conditions seem to warrant. In other words, it merely gives a basis for any estimate that an individual dairyman may see fit to make in regard to his own herd.

VALUE OF PRODUCTS FROM THE AVERAGE DAIRY COW IN NEW YORK STATE*

4,410 lbs. milk at $1.50 per 100 lbs.	$66 15
4,410 lbs. milk (3.8 per cent fat plus $\frac{1}{6}$) = 195.5 lbs. butter, at 35 cents	68 43
4,410 lbs. milk (9 lbs. milk for 1 lb. cheese) = 490 lbs. cheese, at 13 cents	63 70
Average	$66 09

COST OF FOOD AND MAINTENANCE *

26 weeks pasture at 30 cents	$7 80
40 lbs. silage per day for 180 days at $3.50 per ton	12 60
10 lbs. hay per day for 180 days at $12 per ton	10 80
1,470 lbs. grain at $30 per ton (1 lb. of grain for each 3 lbs. of milk, or 7 lbs. per day for 7 months)	22 05
Cost of food	$53 25
Depreciation, $25 in five years, per year	5 00
Interest on investment, $75 per cow at 6 per cent	4 50
Balance available to pay for labor	3 34
Total	$66 09

From this estimate it appears that the owner of the average dairy cow will have about $4.25 to pay for labor. Whether or not this is a sufficient amount, each owner must determine for himself. On the basis that it would require the entire labor of one man to feed, care for, and milk twenty cows, it would mean a labor return of only $85 for the year, which is far below the lowest wage paid to ordinary farm labor.

It may be concluded that the average cow yields small return to her owner for the labor expended on her, and it seems safe to assume that, in order to place dairy farming on a satisfactory basis, cows that will produce more than 4,500 pounds of milk per year are necessary. That such cows have existed and can be produced is shown by Table 2, since the average production in many counties is appreciably above that of the State at large. These figures would undoubtedly be still more striking if the poor cows all through the State could be separated from the large producers. All evidence goes to show that the dairy business maintains a fairly profitable status only because good individual producers make up for the deficiencies of poor ones.

VALUE OF RECORDS

The elimination of low-producing animals is without doubt the first step toward improvement, and this elimination cannot be brought about successfully unless records of production of each cow are kept systematically. Along with such records of production, it is at least highly desirable,

* No charge has been made in this estimate for use of buildings and equipment, nor is any credit given to the animal for manure.

if not absolutely essential, that a record of food consumed be kept as well. There is no reason why any dairyman cannot himself keep the records that are necessary for this selection. If a dairyman keeps his own records, he is more likely to make intelligent and profitable use of them than if they are kept for him by some one else. The fact that most dairymen do not keep such records has led to the formation of cow-testing associations. By cooperative effort, a dairyman may obtain at small cost information that in most cases he would not take the trouble to obtain for himself.

COW-TESTING ASSOCIATIONS

Cow-testing associations may be organized in various ways and under various plans, and each association should be organized with due regard to its own local conditions. The essential feature in any organization is to employ a reliable, painstaking man to do the work. Such organizations have been in successful operation for several years, and it would seem that the time is ripe for the dairymen of New York State to avail themselves more generally of these organizations, in order to make business more satisfactory and more profitable.

The Delhi cow-testing association

The best argument for the formation of a cow-testing association in any given locality is to show the benefits that have already been obtained elsewhere. Such an illustration may be taken from the results of the cow-testing association at Delhi in Delaware county, as reported in Bulletin 30 of the Department of Agriculture, State of New York, December, 1911. These results appear in the following table:

TABLE 3. AMOUNT OF MILK DELIVERED TO FACTORY PER COW

Herd	April, 1909, to March, 1910		Association year, April, 1910, to March, 1911		Increase for association year	
	Number of cows	Pounds of milk	Number of cows	Pounds of milk	Pounds	Percentage
1	37	3,488	37	5,090	1,602	46
2	16	5,027	16	6,446	1,419	28
3	24	4,030	18	5,294	1,264	31
4	45	3,641	50	4,708	1,067	29
5	25	2,985	25	3,755	770	26
6	60	4,171	60	4,933	762	18
7	28	4,261	28	4,934	673	16
8	25	5,174	25	5,423	249	5
9	34	4,090	34	4,397	307	8
10	35	5,263	35	5,527	264	5
11	40	5,173	40	5,182	9	0
12	34	5,119	34	5,096	—23	—0
13	30	4,437	30	4,369	—68	—2
14	36	3,863	36	3,550	—313	—8

The above table reveals several matters of interest. Perhaps the most striking fact is that a cow-testing association tests the owners as well as

the cows. Of the fourteen owners represented in the association, four received no benefits whatever, at least so far as the production of their animals was concerned. Five owners increased the productiveness of their cows more than 25 per cent in a single year, and in one case 46 per cent. External evidence showed that this improvement came only through the weeding out of animals whose inferiority was revealed by the results of the tests made by the association. It should be noticed also that those herds which were made up of high-yielding animals were capable of improvement as well as those in which the cows yielded much less; a comparison of herds 1 and 2 shows this clearly. In respect to herd 3, it is of interest to note that in the association year 18 cows produced within 1,500 pounds as much as 24 cows produced in the preceding year. These herds represent records made in a single locality including about 500 cows. If the 1,500,000 cows of the State were divided into 3,000 groups of 500 each, and each group were tested in the same manner as that of the Delhi Association, the benefits accruing therefrom could scarcely be measured. It would seem as though there were room for 3,000 cow-testing associations in this State.

DETAILS OF ORGANIZATION

The most feasible method of organizing seems to be for twenty-five or twenty-six dairies to form a cow-testing association. Each owner must agree to weigh the milk of each cow every day, and the tester must test the milk of each cow at least for one day of each month. The tester himself may visit the several farms in turn and take samples for making the test, or the owners themselves may take samples and carry them to a central point to be tested. In either case the tester makes the tests, calculates the production of fat of each cow for the month, records the production and the food consumed, and reports regularly to the owner on blanks furnished for the purpose.

The details of carrying out this work may be varied to suit conditions. Experience has shown that an assessment of one dollar for each cow represented in the association will cover the expense of the work for a year in the larger associations, and in some cases it has been done for somewhat less than this.

Official tester

Under any form of organization, much will depend on the official tester employed. First of all he should be a man who will command the respect of the members of the organization. He should be interested in the work. He should be able to make a reliable Babcock test. He should be a reasonably neat penman, fairly rapid and accurate in ordinary arithmetical calculations. Such a man will command $40 to $75 per month.

Apparatus required

Babcock tester — not less than 10-bottle size. If it is to be used in a creamery where steam is available, it should be at least 24-bottle size.

A supply of Babcock glassware (State brand). At least twice as many test bottles as the capacity of the machine, with acid measure, pipettes, thermometer, and other equipment.

Sulfuric acid in sufficient amount. About a pint or two pounds per cow per year.

Sixty-pound spring balance scales, graded to tenths.

As many wide-mouth sample bottles as there are cows in the largest herd to be tested. Each bottle should be supplied with a numbered metal band, or otherwise plainly and durably labeled.

A supply of record blanks, ruled so that the whole record for a cow for a year can be entered on it.

The cost of the above should be approximately as follows:

Wages of man one year at $50 per month	$600 00
10-bottle Babcock tester, $10, ¼ original cost each year	2 50
Extra glassware and breakage	10 00
125 gallons sulfuric acid at 55 cents per gallon	68 75
1 set spring balances	5 00
4 dozen sample bottles	10 00
Record blanks	20 00
	$716 25

Form of agreement

Before a cow-testing association is organized each person who intends to join should sign a definite agreement to that effect, in order that there may be no misunderstanding and that the organization may be put on a substantial financial basis. A simple form for such an agreement is given herewith. Any details necessary or desirable for particular associations should be added, of course.

..................................191...

I, ..., herewith agree to join the .... Cow-testing Association, and I agree to enter....................cows therein, for which I agree to pay to the treasurer of the Association......................dollars for each cow (or....................dollars each month). To be paid on the first day of each month, in twelve payments, from.................. 191.... to ....191....

Signed..............................

In presence of..................................

Constitution of association

Each cow-testing association should be formally organized with the usual officers and with a simple but explicit set of by-laws for its government. It will be a distinct advantage if each association holds stated meetings. There is no reason why a cow-testing association should not be organized as an affiliated association of any local grange, in which case formal by-laws would probably not be necessary. For an independent organization the following might serve as a framework:

Constitution and by-laws of the..........................Cow-testing Association of......................

1. This Association shall be known as the...................... Cow-testing Association.

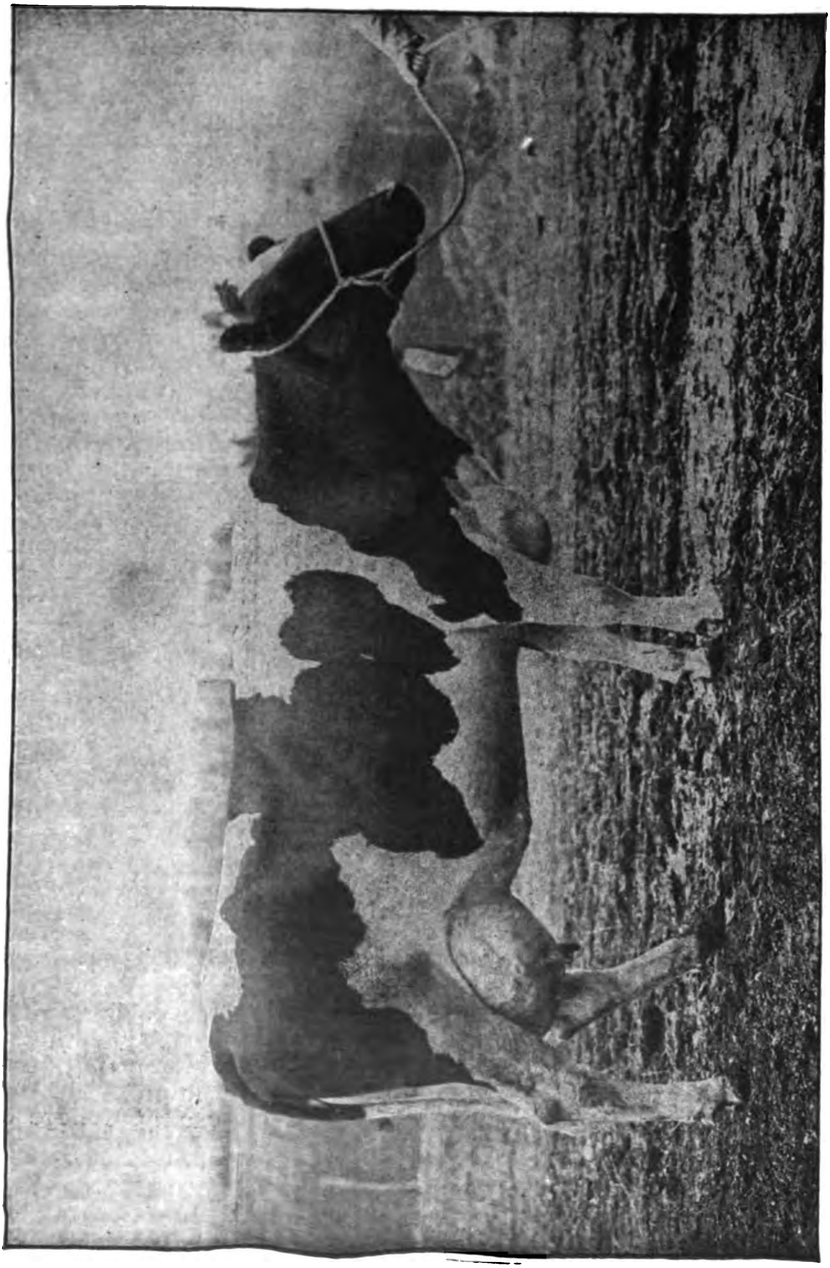

FIG. 57.—*Glista Ernestine 117,999. Bred and owned by Cornell University. Record 24.410 pounds of fat in seven days; 98.948 pounds of fat in thirty days. A good example of improvement by the use of a well-bred sire*

2. The officers shall consist of a President, Vice-president, Secretary, and Treasurer.

3. The officers shall be elected by the members of the Association at the annual meeting, and shall hold office for one year or until their successors are elected.

4. The officers above named shall constitute an executive committee, who shall have general charge of the affairs of the Association.

5. The annual meeting shall be held on the..................day of ....(January or February is suggested).

6. Monthly meetings shall be held at such time and place as shall be designated by the executive committee.

7. The official tester shall be employed by the executive committee, shall continue under its general direction, and shall be responsible to it.

8. No member shall withdraw from the association during the year for which he agreed to join, and each member shall pay a membership fee of $1 for the purposes of the organization.

9. New members may be admitted at any time on vote of the association.

10. These articles may be altered or amended at any regularly called meeting of the association, provided two weeks notice of such amendment is given in writing to the Secretary of the Association.

COOPERATION WITH THE NEW YORK STATE COLLEGE OF AGRICULTURE

In view of the large importance to the dairy interests of the State in obtaining a larger average yield per cow, the New York State College of Agriculture will be glad to cooperate in the formation and operation of cow-testing associations, as follows:

Whenever, in any locality, twenty-five or twenty-six dairymen representing not less than 500 cows are ready to form a cow-testing association, the New York State College of Agriculture, through its Department of Animal Husbandry, will send a representative to assist in perfecting the organization. It is distinctly understood that the New York State College of Agriculture will not canvass for the preliminary organization. The initiative must come from those desiring to engage in the work.

If desired, the College of Agriculture will recommend the services of a competent person to act as tester for the organization, and will oversee his work in the beginning. When possible, it will also send a representative to address a public meeting of farmers or dairymen in order to encourage the formation of a cow-testing association.

In any locality, it will undoutedly be necessary for some public-spirited individual to take upon himself the task of canvassing for the preliminary interest in the organization. Any one engaging in this work and desiring the cooperation of the New York State College of Agriculture should correspond with H. H. Wing, Professor of Animal Husbandry, College of Agriculture, Ithaca, New York.

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Dairy Industry

MILKING MACHINES: THEIR STERILIZATION AND THEIR EFFICIENCY IN PRODUCING CLEAN MILK

Lois W. Wing

Public opinion has been so aroused during recent years that the demand for clean milk has now become insistent. As a result much attention is being given to the best and most economical means for providing the

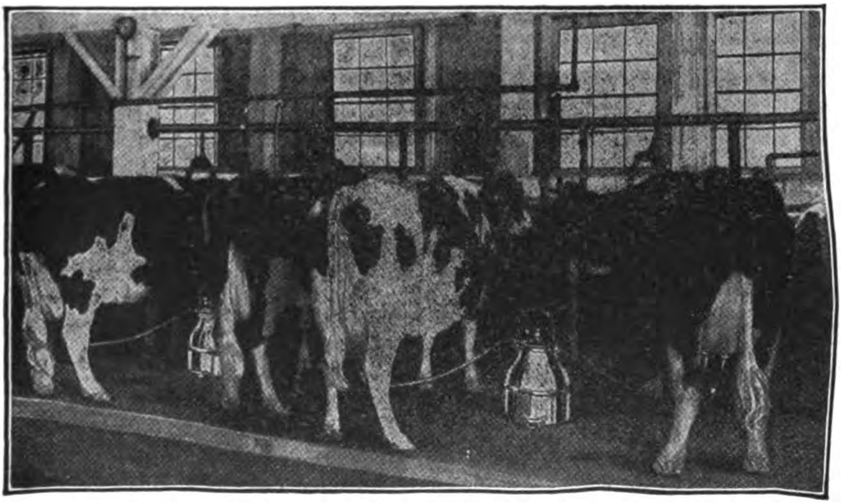

Fig. 58.— *Milkers in use*

clean product. Since it is known that the presence of bacteria and dirt threatens the purity of milk, the aim of the producer is to prevent their introduction.

Under ordinary conditions, the main sources of contamination are the dust and dirt from the body of the cow, the air of the stable, the milker, and poorly washed, non-sterile utensils. By the use of a mechanical device to carry the milk directly from the udder to a covered pail, much of this contamination may be eliminated. When such a device is used one would naturally expect to obtain milk nearly free from dirt and bacteria. **In spite of the fact that the milking machine has greatly reduced con-**

tamination, new factors have been introduced which demand attention. The tubes that carry the milk are long and are made of rubber, and are therefore difficult to clean. Previous investigators have shown that it is possible to produce clean milk with the milking machine, but that great care is needed and much time and labor are required to sterilize the machines.*

In the present series of experiments the writer had two objects in view: first, to test the efficiency of machines in producing a high grade of milk; second, to determine the amount of care necessary in order to keep machines in a sterile condition.

The first experiments were conducted at a laboratory and farm near Little Falls, New York, in the year 1911. The barn was in good condition. The stable was whitewashed and had a plank floor. The feeding alley, mangers, and drop were of cement. The place was fairly clean, although no unusual care was given either the stable or the cows. The machines used throughout the experiment were the Burrell-Lawrence-Kennedy cow-milkers.

COUNTS OF BACTERIA AFTER MACHINES HAD BEEN TREATED IN BRINE SOLUTION

Samples of milk for bacteria counts were taken every night and plated into lactose agar within thirty minutes after milking. Dilutions of 1:100 and 1:50 were used and the plates incubated thirty-six hours at 37° C. The plates were then counted, and the number of bacteria per cubic centimeter of milk were calculated.

From July 19 to 31 inclusive, the machines received the following treatment: After each milking the pails and tubes received a thorough washing with hot water and washing powder. The tubes were then placed in a brine containing about 15 per cent salt (NaCl). Before milking, the pails and tubes were rinsed with hot water. In Table 1 are shown the counts that were obtained when the machines received this treatment:

TABLE 1. BACTERIA PER CUBIC CENTIMETER OF MILK FROM MACHINES THAT HAD RECEIVED THE TREATMENT DESCRIBED ABOVE

Date	Cow 1	Cow 2	Cow 3	Cow 4	Cow 5	Cow 6	Cow 7
July 19	11,125	3,200	......	......	......	1,475	2,825
July 20	2,225	1,750	......	......	......	1,175	1,800
July 21	1,025	700	4,500	1,550	700	1,525	2,150
July 22	650	1,600	800	725	450	1,375	1,425
July 24	687	1,012	537	425	366	750	1,012
July 25	487	975	285	325	425	875	1,087
July 26	1,437	1,250	937	5,012	4,337	8,237	912
July 27	1,350	2,250	287	8,112	212	812	337
July 28	1,637	12,300	2,637	400	925	2,850	10,550
July 29	687	4,512	150	750	1,312	1,125	612
July 31	1,050	1,100	661	350	500	1,288	483
Average	2,033	2,786	1,199	1,961	1,025	1,953	2,108

*Bulletin 92, Bureau of Animal Industry, United States Department of Agriculture. Bulletin 47, Connecticut (Storrs) Agricultural Experiment Station.

The counts in this table indicate that the milk was of good quality from the bacteriological standpoint. They are higher, however, than the usual germ content of the cow's udder and indicate the existence of an external source of contamination.

In order to find this suspected source of contamination, samples were taken from the brine in which the rubber tubes and the teat-cups were treated. The samples were taken from different parts of the tank and plated for bacteria. So many colonies developed in the culture plates that it was impossible to count them. It was evident that the brine solution was not keeping the rubber tubes sterile, and that other solutions with germicidal as well as antiseptic properties must be sought. The use of salt in the solution is advisable because of its powers as a preservative for rubber.

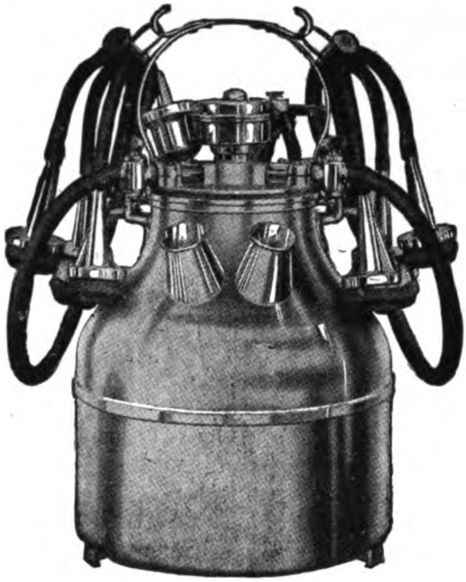

FIG. 59.— *Milker ready for use*

TESTS OF BRINE SOLUTION IN COMBINATION WITH OTHER MATERIALS

Experiments 1, 2, 3.—In order to learn the sterilizing power of certain other materials which could be used with the salt, some brine that had been in use for a week was divided into three parts. To the first was added one part in ten of hydrogen peroxid (H_2O_2); to the second, one part in ten of alcohol; and to the third, two teaspoonfuls of permanganate of potash ($KMnO_4$). In Table 2 is shown the influence of these substances on the development of bacteria when used with the salt solution:

TABLE 2. INFLUENCE OF ALCOHOL, HYDROGEN PEROXID, AND PERMANGANATE OF POTASH ON BACTERIA

Time	Bacteria per cubic centimeter		
	Brine and hydrogen peroxid (H_2O_2)	Brine and alcohol	Brine and permanganate of potash ($KMnO_4$)
7 hours	300	675	Sterile
24 hours	612	975	Discarded
52 hours	1,387	1,250	....

Before the other materials were added, the original count of brine was 330,000 bacteria per cubic centimeter. It will be noted that each of these substances gave a marked reduction in the germ content of the brine. Because of objectionable deposits on the teat-cups, the potassium perman-

ganate was discarded, despite the fact that it was effective as a germicide. The denatured alcohol did not prove satisfactory because it produced an unsightly precipitate and was too expensive for common use. The hydrogen peroxid, in addition to being expensive, seemed to lose its efficiency rapidly, and it attacked the tinning on the teat-cups.

Experiment 4.— A solution of formaldehyde was used next and the results were excellent. It was possible, however, to detect formalin in the milk if the tubes were not rinsed before the milking. Since formalin is held in ill repute as a preservative for milk, it was rejected.

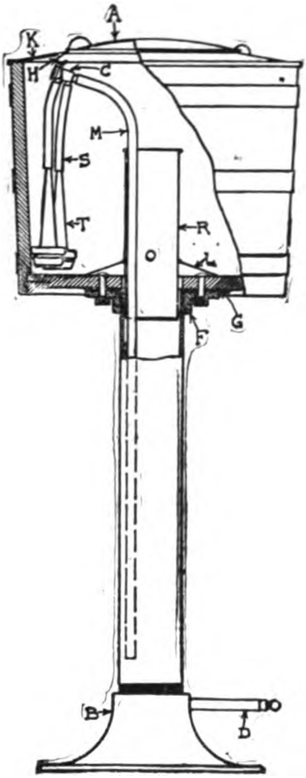

FIG. 60.— *Tank for chlorid-of-lime solution for sterilizing rubber tubes and teat-cups*

Other experiments.— Other germicides and antiseptics, such as vinegar, acetic acid, and copper sulfate ($CuSO_4$), were tried and for one reason or another discarded. Steam and boiling water were not used, because it is difficult to force steam through long rubber tubes and ordinary steaming is not sufficient to produce a sterile condition. Moreover, continued steaming is injurious to the rubber. Although steam is becoming rather common on dairy farms, many farmers do not have it, and the purpose of these experiments was to find a method of cleaning available for every one.

TESTS WITH CHLORID OF LIME

Finally, chlorid of lime was suggested. At the present time this chemical is one of the most popular disinfectants. It is particularly desirable because of its cheapness and availability. The action of chlorid of lime is through hypochlorites, which unite with the organic matter and liberate ozone, a powerful germicide. The odor, which is considered objectionable by some persons, cannot be detected in the milk, even if the tubes are taken directly from the solution without being rinsed.

Experiment 1.— A solution was made as follows:

Water.............	72 pounds..........	——
Salt................	10 pounds..........	$0.07
Chlorid of lime.....	½ pound	.03
		$0.10

After the evening milking, the rubber tubes and the teat-cups were rinsed with cold water and placed in this solution. In the morning, immediately before milking, they were taken from the solution and rinsed with hot water. After the morning milking, the tubes were rinsed with cold water, then with hot water and washing powder, and were again placed in the

solution. As there was no steam on the farm, the pails were merely given a good washing with hot water and washing powder. In Table 3 are given the counts of bacteria in the milk when the machines were treated in this way:

TABLE 3. BACTERIA PER CUBIC CENTIMETER OF MILK AFTER MACHINES HAD BEEN TREATED IN SOLUTION OF CHLORID OF LIME

Date	Cow 1	Cow 2	Cow 3	Cow 4	Cow 5	Cow 6	Cow 7
August 14	324	3,125	112	62	250	462	512
August 15	433	787	337	212	487	975	675
August 16	87	1,187	237	187	812	375	387
Average	281	1,700	229	154	516	604	525

A comparison of the counts of bacteria given in this table with those in Table 1 shows a marked reduction resulting from the use of chlorid of lime. In fact, some of the counts are no greater than might be obtained in milk taken directly from the udder and free from external contamination. This would indicate that the tubes and teat-cups were nearly, if not quite, sterilized by the salt (NaCl) and chlorid-of-lime solution ($CaOCl_2$).

Experiment 2.— At this point the work at Little Falls was discontinued, and subsequent experiments were carried on at Ithaca. The work was conducted at the university dairy barn and the bacteriological laboratory. Some preliminary work was required in order to determine the strength of the chlorid-of-lime solution necessary to obtain the desired results. Experiment 2 consisted of a series of bottles made up as shown by Table 4:

TABLE 4. EFFICIENCY TESTS OF CHLORID OF LIME

Number	Water (cubic centimeters)	Milk (cubic centimeters)	Salt (grams)	Chlorid of lime 1-per-cent solution (cubic centimeters)	Percentage of free chlorin	Bacteria per cubic centimeter	
						After 3 hours	After 7 hours
Check	100	1	......	......	......	8,640,000	11,840,000
A	100	1	......	1	.01	1,950	24,320
B	100	1	......	5	.05	2,850	1,300
C	100	1	......	10	.10	585	275
D	100	1	......	25	.20	312	375
E	100	1	......	50	.33	150	225
F	100	1	5	1	.01	100	500
G	100	1	5	5	.05	0	100
H	100	1	5	10	.10	110	275
I	100	1	5	25	.20	62	187
J	100	1	5	50	.33	300	75
K	100	1	10	1	.01	250	0
L	100	1	10	5	.05	2,075	150
M	100	1	10	10	.10	165	220
N	100	1	10	25	.20	312	125
O	100	1	10	50	.33	375	0

It may be seen that the presence of chlorid of lime in sufficient amounts to yield even .01 per cent of free chlorin reduced decidedly the number of bacteria in the solutions. This is shown by a comparison of the bottles containing chlorin with the check bottle at the top of the table.

Experiment 3.— Experiment 3 was similar to Experiment 2, except that in certain bottles calcium peroxid was added. Although it had some effect, as shown by Table 5, its use was discontinued because of the expense and the trouble of obtaining it:

TABLE 5. GERMICIDAL PROPERTIES OF CHLORID OF LIME

Number	Water (cubic centimeters)	Milk (cubic centimeters)	Salt (grams)	Calcium peroxid (grams)	Chlorid of lime 1-per-cent solution (cubic centimeters)	Percentage of free chlorin	Bacteria per cubic centimeter after 7 hours
Check......	100	1	......	......	....	....	1,245,000
1.........	100	1	......	......	1	.01	550
2.........	100	1	......	......	2	.02	100
3.........	100	1	......	......	3	.03	50
4.........	100	1	......	......	5	.05	0
5.........	100	1	......	......	10	.10	0
6.........	100	1	......	......	25	.20	0
7.........	100	1	......	......	50	.33	0
11.........	100	1	10	......	1	.01	350
12.........	100	1	10	......	2	.02	0
13.........	100	1	10	......	3	.03	50
14.........	100	1	10	......	5	.05	0
15.........	100	1	10	......	10	.10	0
16.........	100	1	10	......	25	.20	0
17.........	100	1	10	......	50	.33	0
21.........	100	1	10	$\frac{1}{4}$	1	.01	0
22.........	100	1	10	$\frac{1}{4}$	2	.02	0
23.........	100	1	10	$\frac{1}{4}$	3	.03	0
24.........	100	1	10	$\frac{1}{4}$	5	.05	0
25.........	100	1	10	$\frac{1}{4}$	10	.10	0
26.........	100	1	10	$\frac{1}{4}$	25	.20	0
27.........	100	1	10	$\frac{1}{4}$	50	.33	0
31.........	100	1	10	$\frac{1}{8}$	....	....	575
32.........	100	1	10	$\frac{1}{4}$	....	....	425
33.........	100	1	10	$\frac{1}{2}$	....	....	250
34.........	100	1	10	$\frac{3}{4}$	....	....	50
35.........	100	1	10	1	....	....	0
36.........	100	1	10	2	....	....	0
37.........	100	1	10	......	....	....	980,000

Experiment 4.— The fourth experiment showed conclusively that chlorid of lime is an efficient germicide.

A tank was filled with a solution consisting of chlorid of lime, salt, and water. Two sets of tubes with cups attached were used. They were filled with sour milk or buttermilk, allowed to soak for a few minutes, then drained and placed in the solution. After eight hours the tubes were

removed from the tank and rinsed on the inside with 400 cubic centimeters of sterile water. The rinse water and the solution in the tank were each plated and the percentage of available chlorin was determined. It was found that if the percentage of chlorin was below .02 per cent the germicidal action was slight. The following table shows this clearly. It will be noted that the percentage of chlorin was low to begin with. It decreased until it reached .01 per cent, when the bacteria became very numerous. After more chlorid of lime was added, the chlorin rose to .05 per cent. This reduced the bacteria to a low point, but the count increased again with the decrease of available chlorin.

TABLE 6. SHOWING THE EFFECT OF A LOW PERCENTAGE OF AVAILABLE CHLORIN

Date	Percentage of chlorin	Hours of exposure	Bacteria per cubic centimeter	
			In solution	In rinse water*
November 17	0.100	14	3	31
November 18	0.020	24	2	101
November 20	0.040	48	2	9
November 21	0.027	24	2	18
November 21	0.027	8	48	165
November 22	0.020	16	13	4
November 22	0.020	8	1,344	1,408
November 23	0.013	16	Too many	184
November 23	0.050	8	23	2
November 24	0.048	16	8	81
November 24	0.034	8	5	64
November 25	0.027	16	3	125
November 25	0.013	48	9	4,896

* 400 cubic centimeters of sterile water with which the tubes were rinsed after treatment in the solution.

Experiment 5.— In Table 7 is shown clearly the extreme germicidal action when a higher percentage of chlorin is used in the solution:

TABLE 7. SHOWING THE EFFECT OF A STRONGER SOLUTION OF CHLORID OF LIME

Date	Percentage of chlorin	Hours of exposure	Bacteria	Material plated
November 27	0.70	8	2	Solution
November 27	....	8	6	Rinse water
November 28	0.66	16	2	Solution
November 28	....	16	0	Rinse water
November 28	0.58	8	1	Solution
November 28	....	8	0	Rinse water
November 29	0.40	16	0	Solution
November 29	....	16	12	Rinse water
November 29	0.32	8	0	Solution
November 29	....	8	0	Rinse water
November 30	0.24	16	2	Solution
November 30	....	16	2	Rinse water

It will be noted that in several cases no bacteria were found in the sterile water with which the tubes were rinsed. When bacteria were found, the numbers were so small as to be of no significance from the standpoint of their effect on the germ content of milk. The tubes were practically sterile after standing in this solution.

Experiment 6.— The following table is interesting in that the numbers of bacteria in the rinse water show an increase if the chlorin drops below .1 per cent. The table shows also that the natural decrease in chlorin in a tank of this size is rapid enough to demand a fresh amount of chlorid of lime about once a week. The solution used in this experiment was as follows:

Water	72.0 pounds
Salt	7.2 pounds
Chlorid of lime	0.5 pound

TABLE 8. SHOWING THE DECREASE OF CHLORIN AFTER STANDING

Date	Percentage of chlorin	Hours of exposure	Bacteria per cubic centimeter: In solution	Bacteria per cubic centimeter: In rinse water
December 21	0.62	16	12	0
December 21	0.62	8	0	1
December 22	0.54	16	5	0
December 22	0.52	8	1	0
December 23	0.44	16	2	0
December 27	0.25	24	3	0
December 28	0.10	24	10	6
December 29	0.03	24	3	345
December 30	0.03	24	5	400

Experiment 7.— In order to determine the value of the chlorid-of-lime solution under the conditions that existed in the earlier trials, another series of counts was made at the farm near Little Falls. The results are shown in Table 9:

TABLE 9. BACTERIA PER CUBIC CENTIMETER OF MILK AT LITTLE FALLS

Date	Cow 1	Cow 2	Cow 3	Cow 4	Cow 5	Cow 6
December 1	1,055	800	......	......	2,740	525
December 2	930	350	3,150	12,800	6,120	4,650
December 2	1,580	650	7,650	7,150	1,200	1,100
December 3	1,650	1,250	5,850	3,125	1,000	925
December 4	475	400	2,100	825	1,150	1,700
December 4	800	700	1,450	1,750	1,300	750
Average per cow General average, 2,342	1,081	691	4,040	5,130	2,251	1,608

It will be seen that most of the counts given in this table are low. In fact, there is only one count in the entire series which is not well within

the limits for "certified" milk. The results would indicate that it is possible to get low bacteria counts with the use of milking machines, when the rubber tubes and the teat-cups are kept properly sterilized by the chlorid-of-lime solution.

TEST UNDER ORDINARY FARM CONDITIONS

In the work described thus far, the machines were washed after each milking before being placed in the germicidal solution. In order to show what might be the result if the machines were not thoroughly washed each day, a series of trials were made at the university barns in 1912, in the following manner: The rubber tubes and metal teat-cups were placed in the chlorid-of-lime solution immediately after milking, without having the milk rinsed out of them. The top of the machine was washed with warm water and washing powder and the pails were sterilized in steam. Once each week the rubber tubes and the teat-cups were thoroughly cleaned with hot water, washing powder, and long brushes. The purpose of these trials was to show what would happen if the machines were in the hands of a farmer who did not have them washed properly each day but did use the chlorid-of-lime solution for the treatment of the tubes. Although it was not done in this case, it would probably have been desirable to run cold water through the tubes before placing them in the germicidal solution, even in the case of this rather careless treatment.

TABLE 10. COMPARISON BETWEEN HAND AND MACHINE METHODS

Date	Bacteria per cubic centimeter of milk	
	By hand method	By machine method
March 28	300	4,950
March 29	250	6,050
March 30	550	6,000
April 1	700	4,700
April 14	350	4,100
April 15	350	3,100
April 16	700	5,700
April 17	400	1,800
April 18	750	1,800
April 19	400	700
April 21	400	1,650
April 22	250	1,750
April 23	150	3,200
April 24	250	2,200
April 25	50	1,700
April 26	300	3,400
April 27	50	1,900
April 28	2,900	4,600
April 29	100	2,400
April 30	850	1,050
May 1	100	2,300
May 2	1,100	2,600
May 3	50	1,500
May 4	1,000	4,500
Average	513	3,068

In order to make the work represent as nearly as possible what would occur on an ordinary dairy farm, the treatment of the machines and the process of milking were left entirely to the barn men. Samples for bacteria counts were taken from the cans after they had been filled by the milkers. A study of the last column in Table 10 shows that these counts are considerably higher than those given in Table 9. This must be expected if the machines are treated in a careless manner. However, in spite of the less careful treatment given the machines, all the counts in this series came well within the requirements for certified milk. This work would seem to indicate that it is possible, even without extreme care, to obtain milk with satisfactory bacteria counts by the use of milking machines, and that such milk can be classed readily as " high grade " so far as the germ content is concerned.

In order to compare the results of machine-milking with those of hand-milking in the same barn, a series of samples taken from milk drawn by hand are given in the second column of Table 10. The very low counts recorded here are evidence of the care used in hand-milking in this stable. While the milk drawn by hand contained uniformly fewer bacteria than the machine-drawn milk, all the samples recorded in this table represent milk of good quality from a bacterial point of view.

CONCLUSIONS

The work described in this bulletin would seem to justify the following general conclusions:

1. The brine solution, which has been generally used for the treatment of the rubber tubes and the teat-cups, does not keep them in a sterile condition.

2. In spite of the fact that the milking-machine excludes external contamination in a marked degree, the milk may still have a high bacteria count resulting from contamination in the rubber tubes.

3. The rubber tubes and the teat-cups may be kept in a practically sterile condition by the use of a salt solution containing chlorid of lime.

4. Fresh chlorid of lime must be added frequently to the solution in the tank, in order to maintain sufficient strength to sterilize the rubber tubes and the teat-cups.

5. If the machines are kept in a sterile condition, it is possible to obtain milk with low bacteria counts.

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Department of Plant Pathology

LATE BLIGHT AND ROT OF POTATOES

M. F. BARRUS

The late blight and rot of potatoes, known also as downy mildew, is very serious during wet years in the northeastern parts of the United States and the adjacent parts of Canada. It is well known in Europe and occurs in all humid climates where potatoes are grown. The disease probably originated in South America, the home of the potato, and was introduced into Europe from which place it spread to America about 1840.

Epidemics of this disease have been very destructive. The destruction of potato vines in Ireland by this disease brought about the famine in that country in 1845. At that time the epidemic spread over the British Isles, Germany, Belgium, and North America. Epidemics of the disease have caused heavy losses in this State. Ten millions of dollars would be a conservative estimate of the loss to New York potato-growers alone in 1912, and the loss each year from 1903 to 1905 was even greater. If weather conditions are favorable, the loss in 1913 and in subsequent years will be enormous unless remedial measures are more generally adopted.

SYMPTOMS OF THE DISEASE

On the leaves of the plant the disease manifests itself in dark, water-soaked areas that later turn brown and dry. These spots may appear at the margin, at the tip, or even at the center of the leaves. If the weather remains moist the spots enlarge rapidly, often involving the entire leaf in one to four days. A fine, mildewy growth appears over the diseased area on the underside of the leaf, especially at the margins of the spots. The affected tissue softens and decays, and gives off a characteristic potato-blight odor. The disease attacks the stems also, producing lesions similar in character to those on the leaves.

The first attack of the season usually comes after the blossoming period of the plant. The lower leaves of vines coming from diseased tubers and the leaves of neighboring vines are first affected. This infection is slight and is generally not noticed. When weather conditions are favorable the disease spreads rapidly to other vines, and the diseased areas in the field are thus ever enlarging. If dry weather prevails after a slight attack,

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